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Scallop Production Areas in the Bay of Fundy: Stock Status for 2012 and Forecast for 2013

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress r7eports on ongoing investigations.

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ABSTRACT

This document reviews the status of scallop stocks in Scallop Production Areas (SPAs) 1, 2, 3, 4, 5, and 6 (Bay of Fundy and Approaches) for 2011/2012 with advice for 2012/2013. The Bay of Fundy is fished by three separate scallop fishing fleets: Full Bay, Mid Bay, and Upper Bay. The Full Bay fleet fishing season is from 1 October to 30 September, while the Mid and Upper Bay fleet season is from 1January to 31 December.

In this assessment, the temporal patterns in condition and stock composition are used to calculate overall growth parameters for use in population models. Improvements made to the models in the 2010/2011 assessment, and changes in survey stratification, were used again in this assessment. In 2012, changes were made to the survey gear used in areas 1A, 1B, 3 and 4. Analyses of a comparative survey show that the new gear does not require a conversion factor, and therefore does not impact the survey catch time series (results presented in Smith et al. 2013).

The Full Bay fleet caught 209 t against a Total Allowable Catch (TAC) of 200 t in SPA 1A in 2011/2012. Condition in this area increased but there was little change in survey biomass. Population biomass estimated by the model was 1,277 t (meats) in 2012, up slightly from the estimate of 1,179 t for 2011 and approximately equal to the median (1997 to 2011) biomass of 1,222 t. A catch of 200 t in 2012/2013 should correspond to the reference exploitation rate (0.15), and is projected to result in a 9.4% decline in biomass for 2013.

The Full Bay fleet caught 161 t against a TAC of 152.25 t in SPA 1B in 2012/2013. The Mid Bay fleet caught 103 t against a TAC of 107 t, and Upper Bay fleet caught 39.9 t against a TAC of 40.59 t. Catch rates for the fleets have been stable, except in 28D which had declining catch rates. Population biomass estimated by the model was 1,743 t (meats) in 2012, essentially unchanged from the estimate of 1,781 t for 2011 and below the median (1997 to 2011) biomass of 1,870 t. A catch of 325 t for 2012/2013 should correspond to the reference exploitation rate (0.15), and is projected to result in a 0.1% increase in biomass for 2013.

For the 2011/2012 fishing season, SPA 3 was split into two areas, 3A and 3B, and a separate quota was allocated to each area. In SPA 3A, which included St. Mary's Bay and the Eastern portion of the Brier/Lurcher area, Full Bay fleet caught 261.7 t from a TAC of 225 t. In SPA 3B, the Western portion of the Brier/Lurcher area, a TAC of 75 t was set so the fishing Industry could explore the area. Full Bay fleet only caught 2.6 t of the TAC in SPA 3B. Catch rates in St. Mary's Bay declined from 2010/2011, but increased in Brier/Lurcher. Population biomass estimated by the model was 1,039 t (meats) in 2012, an increase of 14% from the estimate of 914 t for 2011, which was the median biomass from 1996 to 2011. The population model underestimated the median biomass in 2012, due in large part to higher than expected productivity, as recruitment continues to be low in this area. A catch of 175 t for 2012/2013 should correspond to the reference exploitation rate (0.15) and is projected to result in a 2% decline in biomass.

The Full Bay fleet caught a total of 114 t against a TAC of 120 t in SPA 4 in 2011/2012. Catch rates in this area were at the long-term median. Recruitment in this area continues to be low, and 2012 was a low point in the time series for recruits seen in the survey. Population biomass estimated by the model was 716 t (meats) in 2012, an increase of 5% from the estimate of 681 t for 2011 and just below the median (1983 to 2011) biomass of 754 t. A catch of 110 t should correspond to the reference exploitation rate (0.15) and is projected to result in a 12.7% decline in biomass in 2013.

In SPA 5, landings were 6 t against a TAC of 10 t. Catch rates declined and are below the long-term median, and are the fourth lowest since 1997. The annual survey was discontinued in this area as of 2009 and prospects of future recruitment events are unknown.

A total of 55.5 t was caught in SPA 6 against at TAC of 140 t. Full Bay fleet caught less than 1 t of their 21 t TAC, and Mid Bay fleet caught 54.7 t of their 119 t TAC. Mid Bay fleet catch rates decreased in all areas of SPA 6 and are below long-term averages. Survey abundance has decreased in this area, most significantly in SPA 6A, while condition improved. Trends for the catch rate and the survey in this area suggest that biomass in SPA 6 has declined in 2012.

Zones de production du pétoncle dans la baie de Fundy: état du stock en 2012 et prévisions pour 2013

RÉSUMÉ

Le présent document passe en revue l'état des stocks de pétoncles dans les zones de production du pétoncle (ZPP) 1, 2, 3, 4, 5 et 6 (baie de Fundy et ses environs) pour 2011-2012, et contient des conseils pour 2012-2013. Trois flottilles de pêche du pétoncle distinctes pêchent dans la baie de Fundy, soit la flottille de la totalité de la baie, la flottille du milieu de la baie et la flottille de la partie supérieure de la baie. La saison de pêche de la flottille de la totalité de la baie s'étend du 1er octobre au 30 septembre, tandis que la saison de pêche des flottilles du milieu et de la partie supérieure de la baie s'étend du 1er janvier au 31 décembre.

Dans cette évaluation, les tendances temporelles de la condition et de la composition des stocks sont utilisées pour calculer les paramètres de croissance globale qui seront utilisés dans les modèles de population. Les améliorations apportées aux modèles de l'évaluation de 2010-2011 et les changements apportés à la stratification des relevés ont été utilisés de nouveau dans cette évaluation. En 2012, des changements ont été apportés aux engins du relevé utilisés dans les zones 1A, 1B, 3 et 4. Les analyses d'un relevé comparatif montrent que les nouveaux engins ne nécessitent pas de facteur de conversion et qu'ils n'ont donc pas de répercussions sur la série chronologique des prises du relevé (résultats présentés dans l'étude de Smith *et al.* 2013).

La flottille de la totalité de la baie a capturé 209 t, par rapport à un total autorisé des captures (TAC) de 200 t dans la ZPP 1A en 2011-2012. La condition des stocks dans cette zone s'est améliorée, mais il y a eu peu de changements dans la biomasse des relevés. La biomasse de la population estimée par le modèle était de 1 277 t (chairs) en 2012, soit légèrement supérieure à l'estimation de 1 179 t pour 2011, et elle était à peu près égale à la biomasse médiane de 1 222 t (de 1997 à 2011). Une prise totale de 200 t en 2012-2013 devrait correspondre au taux d'exploitation de référence (0,15) et aboutir à une baisse de 9,4 % de la biomasse en 2013.

La flottille de la totalité de la baie a capturé 161 t, par rapport à un TAC de 152,25 t dans la ZPP 1B en 2012-2013. La flottille du milieu de la baie a capturé 103 t, par rapport à un TAC de 107 t, et la flottille de la partie supérieure de la baie a capturé 39,9 t, par rapport à un TAC de 40,59 t. Les taux de prise pour les flottilles sont restés stables, sauf dans la ZPP 28D qui a connu un déclin dans ses taux de prise. La biomasse de la population estimée par le modèle était de 1 743 t (chairs) en 2012, pratiquement égale à l'estimation de 1 781 t pour 2011, et elle était inférieure à la biomasse médiane de 1 870 t (de 1997 à 2011). Une prise totale de 325 t en 2012-2013 devrait correspondre au taux d'exploitation de référence (0,15) et aboutir à une augmentation de 0,1 % de la biomasse en 2013.

Pour la saison de pêche de 2011-2012, la ZPP 3 a été divisée en deux zones, 3A et 3B, et un quota distinct a été alloué à chaque zone. Dans la ZPP 3A, qui comprenait la baie St. Mary's et la partie est du secteur de l'île Brier et du haut-fond Lurcher, la flottille de la totalité de la baie a capturé 261,7 t, par rapport à un TAC de 225 t. Dans la ZPP 3B, soit la partie ouest du secteur de l'île Brier et du haut-fond Lurcher, un TAC avait été fixé à 75 t afin que l'industrie de la pêche puisse étudier le secteur. La flottille de la totalité de la baie a seulement capturé 2.6 t du TAC dans la ZPP 3B. Les taux de prise dans la baie St. Mary's ont baissé, par rapport à ceux de 2010-2011, mais ils ont augmenté dans le secteur de l'île Brier et du haut-fond Lurcher. La

biomasse de la population estimée par le modèle était de 1 039 t (chairs) en 2012, une augmentation de 14 % par rapport à l'estimation de 914 t pour 2011 qui reprenait la valeur de la biomasse médiane de 1996 à 2011. Le modèle de population a sous-estimé la biomasse médiane en 2012 principalement en raison d'une productivité plus forte que prévu, bien que le recrutement continue d'être peu élevé dans cette zone. Une prise totale de 175 t en 2012-2013 devrait correspondre au taux d'exploitation de référence (0,15) et aboutir à une baisse de 2 % de la biomasse.

La flottille de la totalité de la baie a capturé 114 t, par rapport à un TAC de 120 t dans la ZPP 4 en 2011-2012. Les taux de prise dans cette zone étaient au niveau du taux médian à long terme. Le recrutement dans cette zone continue d'être faible et les recrues en 2012 avaient atteint un niveau faible dans la série chronologique du relevé. La biomasse de la population estimée par le modèle était de 716 t (chairs) en 2012, soit une augmentation de 5 % par rapport à l'estimation de 681 t en 2011, et elle était très légèrement inférieure à la biomasse médiane de 754 t (de 1983 à 2011). Une prise totale de 110 t devrait correspondre au taux d'exploitation de référence (0,15) et aboutir à une baisse de 12,7 % de la biomasse en 2013.

Dans la ZPP 5, les débarquements étaient de 6 t, par rapport à un TAC de 10 t. Les taux de prise ont diminué et sont inférieurs au taux médian à long terme. Ils sont également les quatrièmes plus bas depuis 1997. Le relevé annuel n'est plus effectué dans cette zone depuis 2009 et les perspectives des périodes de recrutement futures sont inconnues.

Un total de 55,5 t a été capturé dans la ZPP 6, par rapport à un TAC de 140 t. La flottille de la totalité de la baie a capturé moins de 1 t du TAC de 21 t et la flottille du milieu de la baie a capturé 54,7 t du TAC de 119 t. Les taux de prise de la flottille du milieu de la baie ont diminué dans tous les secteurs de la ZPP 6 et sont inférieurs aux moyennes à long terme. D'après les relevés, l'abondance a diminué dans cette zone, surtout dans la ZPP 6A, tandis que la condition des stocks s'est améliorée. Les tendances concernant le taux de prise et les relevés dans cette zone laissent entendre que la biomasse dans la ZPP 6 a diminué en 2012.

INTRODUCTION

The Bay of Fundy is fished by three separate scallop fishing fleets: Full Bay, Mid Bay, and Upper Bay. Full Bay scallop license holders are able to fish scallops anywhere in the Bay of Fundy, and the fleet has traditionally been based in Digby. Mid Bay license holders can fish for scallops on the northern side of the Mid Bay line (Figure 1), and the fleet consists mainly of New Brunswick-based vessels with multiple licenses for different species. Upper Bay license holders fish east of the Upper Bay line, and often are Nova Scotia- and New Brunswick-based multi-species vessels. The Full Bay fleet fishes under Individual Transferable Quotas (ITQs) with a 1 October to 30 September season, while the Mid and Upper Bay fleets fish a competitive quota with a 1 January to 31 December season.

Details on the Scallop Production Areas (SPAs), fleet access, current TACs and landings, and available data sets for stock assessment are given in the table below. No TAC has been set for SPA 2 and fishing can take place subject to special license conditions. The Decision column indicates whether advice is provided in terms of a formal model or simply on the basis of trends in the abundance indices.

Bay of Fundy scallops: Preliminary results for 2012.

SPA	Fleets	TAC (meats, t)	Landings[1] (meats, t)	Survey (strata)	CPUE	Decision
1A	Full Bay	200.0	208.6	1981–2012 (8–16) 1984–2012 (2–8 mile) 1997–2002, 2004–2012 (MBS)	1976–2012	Model
1B	Full Bay	152.3	160.9	1997–2012 (Cape S., MBN)	1982–2012	Model
	Mid-Bay	107.2	102.6	2002–2003, 2005–2012 (UB)	1992–2012	
	Upper Bay	40.6	39.9		1997–2012	
2	Marginal Area					
3A	Full Bay	225	261.7	1996–2012	1996–2012	Model
3B	Full Bay	75	2.9			
4	Full Bay	120	114.1	1981–2012	1976–2012	Model
5	Full Bay	10.0	6.0	1997–2008	1976–2012	Trends
6	Full Bay	21.0	0.82	1997–2003, 2005–2012	1976–2012	Trends
	Mid-Bay	119.0	54.7		1993–2012	
	All	1070	952.1			

1. As of 6 November 2012.

The last formal assessment of the stock status and scientific advice on catch levels for the Bay of Fundy and Approaches was reported in Smith et al. (2012). That assessment contained improvements to the growth and population models used in previous assessments. Improvements made to the models were applied to SPAs 1A, 1B, 3, and 4. In addition, the survey areas for SPA 3 were redefined to correspond to the spatial distribution of fishing.

For the 2012 assessment, changes were made to the survey gear used in SPAs 1A, 1B, 3, and 4. In the past, the survey had been conducted with four-gang Digby drags with rubber washers and without teeth. This was replaced in 2012 with nine-gang steel Miracle gear, with flat tire chafers and two inch teeth. A comparative survey was conducted concurrent to the 2012 Bay of Fundy survey to compare the catch from the two gear types. The results of the comparative work show that the two gears were comparable in catch for both commercial and recruit size scallops and that no conversion factor is needed for the new survey series. For details on the comparative survey and the analyses see Smith et al. (2013). The four-gang Digby gear

continues to be used for the survey in SPA 6, due to difficult fishing conditions and patchiness of the scallop distribution in that area.

In previous assessments of these SPAs, catch levels for the following year had been evaluated for the modelled populations in terms of an exploitation rate target of 0.15, and whether or not the proposed catch would result in a decrease in biomass from the current year. The main goal for this approach is to promote stability in the population biomass until recruitment levels improve. In the Bay of Fundy, recruitment success seems to be determined more by favourable environmental conditions than stock size.

Reference points defined by Department of Fisheries and Oceans (DFO) for its implementation of the Precautionary Approach evaluate catches in terms of lowering exploitation rates and improving levels of stock status (e.g., biomass) such that the productivity of the stock increases (DFO 2006). Previous assessments of scallops in the Bay of Fundy (Smith et al. 2008, Smith et al. 2009) had argued that the lack of a demonstrable stock/recruitment relationship for scallops did not guarantee an increase in productivity at higher levels of biomass. All fisheries managed by DFO will soon be adopting a full Precautionary Approach with reference points defining limits, thresholds, and targets for exploitation and stock status. Approaches for defining reference points for the Bay of Fundy scallop have been developed by DFO Science and passed peer review (Smith and Hubley 2012). DFO Science has begun consultations with the fishing industry about the proposed limits and targets. Until these are accepted, advice for the inshore scallop fisheries will continue to be presented in terms of a reference exploitation rate of 0.15 and the likelihood of a biomass decrease in the following year.

Scallop removals accounted for in the assessment include landings from the inshore scallop fleets and Food Social and Ceremonial (FSC) catch when applicable. Landed recreational and FSC catch by dip netting, diving, tongs, and hand are not recorded and, therefore, not available.

POPULATION MODEL

This assessment models the population dynamics for all SPAs (excluding 5 and 6) using the delay-difference model (Quinn and Deriso 1999) with modifications presented in Smith et al. (2012),

$$B_{t+1} = \left(e^{-m_t} g_t \left(B_t - C_t\right) + e^{-m_t} g_{Rt} R_t\right) \mu_t \qquad (1)$$

where B_t, g_t, and m_t are the population biomass, growth rate of the portion of the population recruited to the fishery, and instantaneous natural mortality, respectively in year t. The term R_t denotes the biomass of the recruiting size classes in year t and g_{Rt} is the growth rate of the portion of the population recruiting to the fishery in year $t+1$. C_t is the commercial catch in year t. The μ_t represents random error associated with the model dynamics. The state-space structure of the model and the Bayesian methods for estimation were reviewed in Smith et al. (2008). The modifications implemented in Smith et al. (2012), and used here, were intended to better estimate and predict biomass by including annual and spatial variability in condition factor for the relationship between meat weight and shell height. Condition factor was calculated as the ratio of meat weight over the cube of the shell height, assuming an isometric length weight relationship (Hubley et al. 2011).

$$CF = \frac{W}{L^3}$$

Spatial patterns of growth and condition were examined and in the case of condition, incorporated into estimates of survey biomass. In order to calculate weight, average shell heights of commercial or recruit size scallops from the survey were converted to meat weights using the annual condition factors.

The annual varying growth rates for the model are the ratios between the observed average meat weight of commercial or recruit scallops and the observed average meat weight of the same scallops the following year. The growth rates (g_t and g_{Rt}) for the model are then calculuated as

$$g_{t-1} = \frac{\overline{w}_t}{\overline{w}_{t-1}}$$

where $\overline{w}_t$ is the average weight of scallops adjusted for condition in year t and $\overline{w}_{t-1}$ is the average weight of those same scallops adjusted for condition in year t-1 (Smith et al. 2012). Natural mortality (m) was estimated within the model using ratio of clappers (dead scallops) to live scallops and the estimated dissolution time (S) (Smith and Lundy 2002a). Other details of the model including the formulation of the prior distributions can be found in Smith et al. (2008) and Smith et al. (2012). No new changes were made to the population models for this assessment.

Model forecasts of biomass require estimates of expected biomass growth (and condition) and natural mortality for future years. These estimates are based on current conditions and therefore may not reflect actual changes over the next two years. Using current conditions to project forward better captures inter-annual variability and changes than using short or long-term means.

SPA 1A: SOUTHWEST BAY OF FUNDY

COMMERCIAL FISHERY

The Full Bay fleet caught 209 t against a quota of 200 t in 2011/2012. For the 2012/2013 fishing season an interim quota of 100 t was set for 1 October 2012. As of 6 November, 0.5 t landings were reported. Annual trends for landings and quotas are presented in Figure 2.

Year	Avg. 02–06[1]	2006/ 2007	2007/ 2008	2008/ 2009	2009/ 2010	2010/ 2011	2011/ 2012	2012/ 2013
TAC (t)	600	150	216	265	300	300	200	100[3]
Landing (t)	465	137	226	267	297	278.1	208.6[2]	0.5[2]

1. Full Bay TAC was split into SPA 1A and SPA 1B in 2002/2003.
2. landings based on quota report 6 November 2012.
3. Interim TAC.

Commercial catch rates in 2011/2012 were 12.1 kg/h, below the long-term median (1995/1996 to 2010/2011) of 15.5 kg/h. Effort also decreased in 2011/2012 and is still above the long-term median (Figure 3).

SURVEY

The 2012 survey in SPA 1A was conducted between June and August and consisted of 148 tows in three subareas (Figure 4): 2 to 8 miles (13 tows), 8 to 16 miles (84 tows), and Middle Bay South (51 tows).

Condition has increased and was above the long-term average of 10.9 g/dm^3 in all subareas of SPA 1A (Figure 5). The greatest increase was observed in Middle Bay South, which increased from 10.9 g/dm^3 in 2011 to 12.7 g/dm^3, while the highest condition at 13.8 g/dm^3 was in the 2 to 8 mile area. The area of highest condition in 2 to 8 mile occurs close to the border between Young's Cove and Hampton (Figure 6; strata 6 and 7 in Figure 4). Condition in Middle Bay South was mostly consistent in areas sampled, but decreased towards the Outer portion of 28D. In the 8 to 16 mile area, condition is greatest from Parker's Cove to Hampton (strata 15–17).

In the 2 to 8 mile area, abundance of recruits (65–79 mm) and pre-recruits (<65 mm) continues to be low (Figure 7), but the survey did show slight increases in the mean number and weight per tow for both commercial (≥80 mm) and recruit size scallops (Figure 8). Recruitment is also low in the 8 to 16 mile area (Figure 9), and there has been virtually no change in the abundance or weight of recruit size scallops since 2010 (Figure 10). The number of commercial size scallops decreased in the 8 to 16 mile area, but there was no change in the weight per tow for commercial scallop (Figure 10). The greatest density of commercial scallop in 1A were seen off and below Digby Gut (strata 12, 13, 19; Figure 11), but meat count and condition in those strata are poor (Figure 12, Figure 6). Pre-recruits were more evenly distributed in the 8 to 16 mile area than in other parts of 1A (Figure 13). Recruits were distributed throughout the 2 to 8 mile area and in 8 to 16 mile area along the mid-bay line (Figure14). There was very little change in the abundance or weight per tow of commercial and recruit size scallops in Middle Bay South (Figure 15). This area continues to be dominated by larger scallops (mode: 125 mm; Figure 16). When the subareas of SPA 1A are combined, there was slight decreases in survey numbers and a slight increase in survey biomass for the area (Figure 17).

POPULATION MODEL

The delay-difference model was fit to the survey and catch data from 1997 to 2012. Stratified survey indices from both the 8 to 16 and 2 to 8 miles area were combined with the index from Middle Bay South. The index for Middle Bay South in 1997 was assumed to be the same as it was in 1998, and other missing years (2003 and 2004) were filled in using simple interpolation. Two chains were generated, each 160,000 samples long with the first 80,000 discarded for burn-in. Retained samples were thinned by 10 to give 8000 samples to estimate the posterior distribution. Trace plots indicated full mixing of chains and convergence. In general, the addition of another year of data changed very little over the results presented in Smith et al. (2012). The model fit the survey mean estimates quite closely for both commercial size and recruit size scallops but did allow for a high amount of uncertainty for the estimates of recruits in 2001 (Figure 18), and the comparison of posterior distributions with the priors indicated that the informative priors for the S term and survey catchability q_I were influential (Figure 19).

STOCK STATUS AND FORECAST

Exploitation and survival estimates (i.e., e^{-m}) are presented in Figure 20. Natural mortality has been quite low since 2008, while exploitation had increased from 2007 levelled off in 2010 and

then declined to 0.14 in 2012. Biomass posterior medians along with 95% credible intervals indicate very little change in the biomass of commercial and recruit size scallops in the last four years (Figure 21). Population biomass estimated by the model was 1,277 t (meats) in 2012, up slightly from the estimate of 1,179 t for 2011 and approximately equal to the median biomass of 1,222 t (1997 to 2011). Biomass is projected to remain constant under the interim TAC of 100 t, which would correspond to an exploitation rate of 0.07. Other catch scenarios for 2012/2013, as well as the catches that correspond to various probabilities of exceeding an exploitation rate of 0.15 the following year (2013/2014), are presented in Table 2.

A catch of 200 t for 2012/2013 should correspond to the reference exploitation rate and is projected to result in a 9.4% decline in biomass for 2013. The probability that biomass would decline at this level of catch is 0.57. If this catch was realized in the 2012/2013 season, then a catch of 193 t next year (2013/2014) would be expected to have a 50% chance of exceeding an exploitation rate of 0.15.

The performance of the model's prediction of biomass in the following year was evaluated by comparing predictions from fits to the data up to year $t-1$ (e.g., 2005) to year t (e.g., 2006) with the estimates of biomass from fitting the model to data up to year t (Figure 22). All of the model estimates fall within the 50% credible interval of the prediction from the previous year.

SPA 1B: NORTHERN/UPPER BAY OF FUNDY

COMMERCIAL FISHERY

The Full Bay fleet caught a total of 161 t against a quota of 152 t in 2011/2012. This is roughly double the catch by this fleet in 2010/2011. An interim quota of 100 t was set for 1 October 2012 for the Full Bay 2012/2013 season and as of 6 November 25.5 t had been landed.

Full Bay

Year	Avg. 02–06[1]	2006/ 2007	2007/ 2008	2008/ 2009	2009/ 2010	2010/ 2011	2011/ 2012	2012/ 2013
TAC (t)	181	200	206.3	195.4	205.5	203	152.3	100[3]
Landing (t)	154	213	210	192.7	151.9	84.2	160.9[2]	25.5[2]

1. Full Bay TAC was split into SPA 1A and SPA 1B in 2002/2003.
2. landings based on quota report as of 6 November 2012.
3. Interim TAC.

The Mid-Bay fleet caught 103 t against a quota of 107 t, and Upper Bay caught 40 t against a quota of 41 t. Trends in TAC and Landings for all three fleets can be seen in Figure 23.

Mid and Upper Bay

Year	Avg. 02–06	2007	2008	2009	2010	2011	2012
TAC (t)[1]	156.3	200	148.3	137.5	144.7	142.9	107.2
MB: Landing (t)	145.8	93	120	142.5	138.6	123.3	102.6[2]
TAC (t)			85.5	52.1	54.8	54.1	40.6
UB: Landing (t)	66.4	79.5	87.4	54.4	54.4	54.7	39.9[2]

1. TAC in 1B for 2002/2003 to 2006-2007 was from MB and UB combined.
2. landings based on quota report as of 6 November 2012.

Full Bay and Mid Bay fleets have had stable catch rates in 28B and 28C over the past couple seasons. Upper Bay catch rates in 28B have shown a very slow decline since 2007. In 28D, catch rates for both Full Bay and Upper Bay decreased in 2011/2012 from last season (Figure 24).

SURVEY

The 2012 survey in 1B took place in July and August and consisted of 146 tows in seven subareas. The survey excluded 28D Inner and the southern portion of Outer 28D as past work has shown these areas to be marginal scallop habitat (Smith et al. 2009).

Cape Spencer (34 tows) had little change in the number per tow and weight of commercial scallop (Figure 25). This area does have regular recruitment (Figure 26), and the mean number of recruits per tow increased from 5.7 to 18.8 per tow (Figure 25). There were recruits and pre-recruits distributed consistently over this subarea (Figure 13, Figure 14).

Middle Bay North (51 tows) had a decrease in the numbers of commercial size scallops, but no decrease in weight (Figure 27), likely due to increased condition in the area. There was an increase in pre-recruit scallop in Middle Bay North (Figure 28). Area 28C (Upper Bay; 31 tows) showed little change in weight per tow for commercial and recruit size scallops. There was a decrease in the number of commercial scallop per tow (Figure 29). There were an increase in pre-recruits observed in this area (Figure 30), and pre-recruits observed last year were observed this year as recruits. The highest density of commercial size scallops spans the border between Middle Bay North and 28C (Figure 11). This was also the location with higher recruit numbers and biomass (Figure 14), as well has high numbers of pre-recruits (Figure 13).

Advocate Harbour (9 tows) has shown good recruitment in the past. The mean number of recruits per tow decreased slightly, however, and commercial numbers and weights also decreased from the previous year (Figure 31). This year, large numbers of pre-recruit scallops (mode 40-45 mm; Figure 32, Figure 13) were seen. Meat counts for commercial scallop in this area were high (Figure 12).

Abundance in the northern portion of 28D Outer (12 tows) is low, with only 17 commercial scallops per tow. There were no recruit scallops recorded in the survey, similar to the surveys in 2003 and 2010 (Figure 33). There is little evidence of pre-recruits in the survey as well (Figure 34).

Spencer's Island (5 tows) saw a large decrease in the number of commercial scallops per tow, from 236 in 2011 to 65.6 this year; this was accompanied by a decrease in weight from 1.5 kg/tow to 0.4 kg/tow. Both are lows in the seven year time series. There was also a decrease in the number and weight of recruit size scallops (Figure 35). Catches of pre-recruits in the survey were very low as well (Figure 36).

Scot's Bay (4 tows) saw increases in weight and number of commercial and recruit size scallops (Figure 37), and there is also an increase in abundance of pre-recruits over the previous year (Figure 38).

Condition in all parts of 1B increased in 2012. All areas were above the long-term (1997-2011) average of 10.7 g/dm^3, and range from 10.9 g/dm^3 in Middle Bay North to 11.4 g/dm^3 in 28C (Upper Bay; Figure 39). The distribution of condition was similar across the subareas of 1B,

with some areas of higher condition in Middle Bay North near the border with Middle Bay South (Figure 6).

Overall, survey biomass in SPA 1B is always greater in Cape Spencer and Middle Bay North (Scallop Fishing Area (SFA) 28B), with all other areas containing lower total biomass (Figure 40). The commercial biomass in 28B did not change this year, and there was an increase in recruit biomass mainly in the Cape Spencer area (Figure 40).

POPULATION MODEL

Survey indices for each stratum in SPA 1B (Cape Spencer, Middle Bay North, Upper Bay 28C, 28D outer, Advocate, Spencer's Island, and Scots Bay) were combined to form a time series from 1997 to 2012. Middle Bay North was divided into two strata by a line from (Lat. 45.237°, Lon. -65.197°) to (Lat. 45.459°, Lon. -65.264°) in order to compensate for variable coverage in early years. The 28D outer strata was modified so that it only included the area north of a line from (Lat. 45.145°, Lon. -65.032°) to (Lat. 45.292°, Lon. -64.775°). Missing data in early years was dealt with by assuming the densities in Upper Bay 28C, 28D outer, Advocate, Spencer's Island, and Scots Bay were the same as Middle Bay North from 1997 to 2000, and from 2001 to 2004 the densities of Spencer's Island and Scots Bay were assumed to be the same as the modified 28D outer strata. Other missing data that occurred in 2004 were estimated by interpolation.

As with SPA 1A, two chains were generated each 160,000 samples long with the first 80,000 discarded for burn-in. Retained samples were thinned by 10 to give 8000 samples to estimate the posterior distribution. Trace plots indicated full mixing of chains and convergence. The model fit the survey mean estimates quite closely for both commercial size and recruits despite a relatively high amount of uncertainty for the estimates (Figure 41). The posterior distributions show well defined posteriors for these parameters and that the prior for the survey catchability q_I was fairly influential (Figure 42).

STOCK STATUS AND FORECAST

Exploitation and survival estimates (i.e., $\exp(-m)$) show natural mortality and exploitation rates being less variable than in other areas (Figure 43). The estimated exploitation rate for 2012 was 0.15. Wide 95% credible intervals for biomass indicate a high degree of uncertainty that possibly reflects the incomplete survey index of the early years in the time series (Figure 44). Population biomass estimated by the model was 1,743 t (meats) in 2012, essentially unchanged from the estimate of 1,781 t for 2011 and below the median biomass of 1,870 t (1997 to 2011). Estimates of recruit biomass increased from a low of 46.3 t to 144 t, which is above the median level of 122 t (1997 to 2011). Biomass is projected to increase to 2014 t under the interim TAC of 100 t, which would correspond to an exploitation rate of 0.05. The probability that biomass would decline at this level of catch is 0.41. Other catch scenarios for 2012/2013, as well as the catches that correspond to various probabilities of exceeding an exploitation rate of 0.15 the following year (2013/2014), are presented in Table 3. A catch of 325 t for 2012/2013 should correspond to the reference exploitation rate (0.15) and is projected to result in a 0.1% increase in biomass. If this catch was realized in the current season, then a catch of 325 t next year would be expected to have a 50% chance of resulting in an exploitation rate greater than 0.15 for 2013/2014.

The performance of the model's prediction of biomass in the next year was evaluated by comparing predictions from fits to the data up to year $t-1$ (e.g., 2005) to year t (e.g., 2006) with the estimates of biomass from fitting the model to data up to year t (Figure 45). All of the model estimates fall within the 50% credible interval of the prediction from the previous year.

SPA 3: BRIER, LURCHER, AND ST. MARY'S BAY

COMMERCIAL FISHERY

The Full Bay fleet caught a total of 264.54 t against a quota of 300 t in 2011/2012. For the 2011/2012 fishing season, the quota in SPA 3 was subdivided into 3A and 3B. Area 3A consisted of St. Mary's Bay and the eastern portion of Brier/Lurcher. Area 3B was the western portion of Brier/Lurcher, which has received little fishing effort in recent years. In 2011/2012, these two areas were managed separately to reflect the different fishing intensities and different densities observed in the survey. The TAC in 3A was set at 225 t and 261.7 t was landed. The TAC in 3B was set at 75 t and 2.9 t was landed.

An interim quota for the whole area for 2012/2013 season of 100 t was set for 01 October 2012 for the Brier/Lurcher area. As of 15 October, 145.2 t had been landed and the area was closed pending the stock assessment. Trends in landings and TAC can be seen in Figure 46.

	Avg. 02-06	2006/ 2007	2007/ 2008	2008/ 2009	2009/ 2012	2012/ 2011	2011/ 2012[1]		2012/ 2013
							A	B	
TAC (t)	250	200	70	60	50	50	225	75	100[3]
Landing (t)	194	109	80.2	63	56	72.96	261.7[2]	2.9[2]	145.2[2]

1. Quota divided into 3A and 3B in 2011/2012.
2. Landings based on quota report as of 6 November 2012.
3. Interim TAC.

Commercial catch rates in 2012 for St. Mary's Bay declined from 2011 (26.5 versus 21 kg/h), while June catch rates for the Brier/Lurcher area in 3A and 3A+3B increased by 17 and 13%, respectively (Figure 47). The increase in catch rate from October 2011 to October 2012 was similar at 19%.

Mean daily catch rates for the four fishing periods from 1 October 2011 to 15 October 2012 are presented in Figure 48. Catch rates for March/April were for area 3B and were low compared to other areas and other times of the year. The catch rates for 3B in June/July were highly variable and lower on average than the catch rates in 3A in June and in October for both years.

Fishing in the Brier/Lurcher area continued to be concentrated in the more inshore part of the area as identified previously using Vessel Monitoring System (VMS) data, which was used to re-stratify the survey for the 2011 assessment (Smith et al. 2012; Figure 49). Some fishing did take place in the Outside area but at generally lower catch rates. Note that the fishery in October 2012 tended to concentrate in the more southerly areas compared to the previous June and October (Figure 50).

SURVEY

The survey in SPA 3 took place in June 2012 and consisted of 150 tows in St. Mary's Bay (25 tows), and Brier Island/Lurcher Shoals (125 tows). As in the 2011 assessment, the

Brier/Lurcher area was separated based on new stratification from VMS data into "Inside" and "Outside" (Figure 49; Smith et al. 2012). This step was taken to ensure that the survey stratification more accurately reflects the area being fished. The Inside area represents the frequently fished areas. The Outside area, the area excluded by the VMS polygon, represents an area that has not been routinely fished in recent years. The Inside area had 64 tows and the Outside area had 61. As in the previous assessment, survey results are presented for St. Mary's Bay and Brier/Lurcher, as well as the Inside and Outside areas of Brier/Lurcher. The management area of 3A from the 2011/2012 season corresponds roughly to the survey area Inside the VMS. There is a portion of the Inside VMS area that is in the management area 3B.

There was little change in the mean number per tow in the subareas of SPA3 (Figure 51), but there was an increase in the mean weight per tow (Figure 52) of commercial scallop in St. Mary's Bay and both parts of Brier/Lurcher. Distribution of commercial scallop was more variable in St. Mary's Bay, and some of the highest densities were seen in the Inside area (Figure 53). The survey again found pre-recruits in St. Mary's Bay, although in lower numbers than 2011 (Figure 54, Figure 55). The number of recruits was similar to 2011 (Figure 54). Pre-recruits were seen in both Inside and Outside areas (Figure 56, Figure 57). The highest concentration of pre-recruits was seen along the border with SFA 29 (Figure 55). There were no areas of high recruit density, but recruits were spread throughout St. Mary's Bay and the Inside area (Figure 58)

The condition factor in St. Mary's Bay decreased, but was still higher than that observed in Brier/Lurcher (Figure 59, Figure 60). Highest conditions were in St. Mary's Bay (Figure 59, Figure 60), with the lowest conditions in the Outside portion of Brier/Lurcher (Figure 59, Figure 60). The higher condition in St. Mary's Bay was also reflected in the generally better meat counts (Figure 61). Contrary to the trend in condition, St. Mary's saw an increase in the average shell height of commerical size scallops, while the inside area saw a slight decrease in mean shell height (Figure 62). The increase in mean shell height for St. Mary's and increased condition for the inside area explains how mean weight per tow increased while mean numbers per tow remained the same for these areas.

POPULATION MODEL

The delay-difference model was fit to the survey and catch data. The catch data was partitioned as occurring either before or after the survey each year to deal with the survey timing changes that have occurred. Given that the 2012 survey occurred after the fishery in June the catch in October 2012 was included in predicting the biomass for next June to correspond to the 2013 survey. Survey indices from both St. Mary's Bay and Brier/Lurcher-Inside were used, combined with the missing years in the former series filled in using simple interpolation. Two chains were generated, each 160,000 samples long with the first 80,000 discarded for burn-in. Retained samples were thinned by 10 to give 8,000 samples to estimate the posterior distribution. Trace plots indicated full mixing of chains and convergence.

The model fit the survey mean estimates quite closely for both commercial size and recruit size scallops, but did allow for a high amount of uncertainty for the estimates of recruits in 2001 (Figure 63). The posterior distributions show well defined posteriors for the estimated parameters (Figure 64).

The performance of the model's prediction of biomass in the next year was evaluated by comparing predictions from fits to the data up to year $t-1$ (e.g., 2005) to year t (e.g., 2006) with the estimates of biomass from fitting the model to data up to year t (Figure 65). While all of the

previous model estimates fall within the 50% credible interval of the prediction from the previous year, the estimated biomass for 2012 was greater than the 75th percentile of the prediction made using data up to 2011 and the actual catch.

The results show that in 2011 and 2012 predictions from the population model have underestimated the median biomass in SPA 3 (Figure 65). Estimates of current and future productivity are based on estimates of recruitment (Figure 63), survival (Figure 66) and condition (Figure 59). Recruitment estimates indicate a small improvement over the last two to three years, while survival has not changed very much in the last four years. The major change in productivity has been the increase in condition in the Inside area since 2010 after declining from 2007 to 2009.

The combination of the three factors given above is referred to as surplus production. This can be estimated on an annual basis by the difference between this year's and last year's biomass plus the landings (Figure 67). The increase in productivity after 2010 is higher for the surplus production rate than expected for condition alone and indicates that with the exception of 2003/2004 and 2006/2007, the productivity rate has been close to or less than 1.0 since 2002. Recent conditions are more similar to those of the late 1990s to early 2000s. Recruitment (Figure 63) and survival (Figure 66) were generally higher in the earlier period than in the last two years while condition was lower in the mid to late 1990s but higher in 1999 to 2001. Overall improvements in condition during the latter years resulted in scallops throughout the area including the lower yield areas (Outside) having higher meat weight at shell height than previously observed. Limited fall re-openings of the fishery restricted to the southern portion of the Outside area occurred in 1999 and 2000 to take advantage of the larger meats in the lower yield areas (Smith and Lundy 2002b). Total landings during this period ranged from 163 to 249 t.

In the last two years, a larger portion of the landings have been occurring in October and at the same time, the differences between commercial catch rates in October and June have been increasing (Figure 47) suggesting increasing growth rates once spawning has occurred. Changes in condition (and growth) for the population model are measured from June one year to June the next year (August to August before 2004) and are not capturing this increased seasonal growth and, hence, underestimating the biomass available to the fishery, especially in October. There is evidence that water temperatures have been warmer in 2011 and 2012 than in recent years, but the implications of these changes on improved scallop condition have not been investigated.

STOCK STATUS AND FORECAST

Exploitation and survival estimates (i.e., $\exp(-m)$) are presented in Figure 66. Since 2011 survival has increased (natural mortality decreasing) while exploitation has increased. The catch of 260 t as of June 2012 corresponded to an exploitation rate of 0.20.

Biomass posterior medians for commercial and recruit size scallops along with 95% credible intervals not surprisingly strongly resemble the survey fits (Figure 68). Population biomass estimated by the model was 1039 t (meats) in 2012, an increase of 14% from the estimate of 914 t for 2011 which was the median biomass from 1996 to 2011. This seems to be in agreement with the trend for the commercial catch rate estimates in Figure 47.

A catch of 175 t for 2012/2013 should correspond to the reference exploitation rate (0.15) and is predicted to result in a 2% decline in biomass. This catch includes the 145 t already landed in

the fall 2012 fishery (Table 4). If this catch was realized in the current season, then a catch of 180 t next year would be expected to have a 50% chance of resulting in an exploitation rate greater than 0.15 for 2013/2014. If the catch was 250 t (including the 145 t already landed), the probability that biomass would decline would be 0.57. This level of catch would be expected to result in a decline of 9.5% and an exploitation rate of 0.21; however, this rate would be lower if biomass was underestimated.

It is apparent landings of 260 t did not result in a decrease in biomass in 2012, and a similar level may be sustainable for 2013 assuming that productivity continues to be high. However, this productivity appears to be mainly due to increased growth as recruitment continues to be low. Mean shell height for commercial size scallops is currently high in the Inside area suggesting that the overall growth potential should start to diminish (Figure 62), and it is unlikely that this increased productivity can be sustained over the next few years without increased levels of recruitment.

SPA 4: DIGBY

COMMERCIAL FISHERY

The Full Bay fleet caught a total of 114 t against a quota of 120 t in 2011/2012. An interim quota for the 2012/2013 season of 100 t was set for 1 October 2012. As of 6 November, 35.5 t had been landed. Trends in landings and TAC can be seen in Figure 69.

Year	Avg. 02–06	2006/ 2007	2007/ 2008	2008/ 2009	2009/ 2010	2010/ 2011	2011/ 2012	2012/ 2013
TAC (t)	710	100	100	100	120	140	120	100[3]
Landing (t)	656	42[1]	79	98	114	138.2	114.1[2]	35.5[2]

1. Landings reported as 68 t in 2007.
2. Landings based on quota report as of 6 November 2012.
3. Interim TAC.

Catch rates in 2011/2012 decreased from 18.7 kg/h to 15.9 kg/h, very close to the long-term median of 16.4 kg/h. Effort has been below the long-term median since 2007 (Figure 70).

SURVEY

The SPA 4 survey consisted of 87 tows. There has been very little change in the mean number of commercial scallop per tow in this area since 2006 (Figure 71), but there was a slight increase in the mean weight per tow of commercial size scallops (Figure 71). Distribution of commercial size scallop was less patchy in SPA 4 than in other areas (Figure 11). Some of the best meat counts were observed in the Digby Gut and nearby strata (strata 3, 9, and 10; Figure 12). Mean numbers of recruits have been low for the past number of years and in 2012 the estimate decreased to 0.9 per tow from 2.2 in 2011. This was the lowest observed estimate for recruits in the 31 year time series (Figure 71); the previous low was 1.1 per tow in 2010. The weight per tow for recruit scallops decreased, but weight is currently above the series low in 2010 (Figure 71). Estimates of recruit biomass were low in the area (Figure 14), and there was little evidence that there will be significant recruitment in the next couple of years. Pre-recruits were present in parts of SPA 4, but in low densities (Figure 72, Figure 13).

The condition factor in SPA 4 decreased slightly to 12.3 g/dm^3, just above the long-term average (Figure 73). Condition was highest above Digby Gut (Figure 6).

POPULATION MODEL

For SPA 4, the delay-difference model was fit to the stratified survey index and catch data from 1983 to 2012. As noted in Smith et al. (2012), in 2,000 scallops at a size that were smaller than what were considered recruits (<65 mm) grew to commercial size the following year because of abnormally favourable growth conditions that year (Smith and Lundy 2002a). To correct this problem, the recruit index was adjusted for 2,000 so that scallops between 40–79 mm were considered recruits. As with the other models, two chains were generated each 80,000 samples long with the first 40,000 discarded for burn-in. Retained samples were thinned by 10 to give 8,000 samples to estimate the posterior distribution. Trace plots indicated full mixing of chains and convergence. The comparison of posterior distributions with the priors indicated that the priors were not highly influential (Figure 74). The posterior distribution of q_I suggests information in the data points to q_I as being somewhat lower in SPA 4 than other areas[1]. The model fits the survey mean estimates quite closely for most years while allowing for uncertainty in estimates of recruitment events in 1987 and 2001 (Figure 75).

STOCK STATUS AND FORECAST

Estimates of survival (i.e., $\exp(-m)$) show the very high levels of natural mortality that occurred 1989–1991 as the result of a catastrophic mortality event. Natural mortality has increased slightly to median levels after being very low in the previous five years. Exploitation decreased in 2012 to 0.14 after rising from 0.07 in 2007 to 0.17 in 2011 (Figure 76). Biomass posterior medians, along with 95% credible intervals, indicate very little change in the biomass of commercial and recruit size scallops in the last four years (Figure 77). Population biomass estimated by the model was 716 t (meats) in 2012, an increase of 5% from the estimate of 681 t for 2011 and just below the median biomass of 754 t (1983 to 2011). Estimated recruitment of 9.0 t in 2012 is among lowest since 1983.

A catch of 110 t for 2012/2013 should correspond to the reference exploitation (0.15) and is projected to result in an 12.7% decline in biomass. The probability that biomass would decline at this level of catch is 0.60. Other catch scenarios for 2012/2013, as well as the catches that correspond to various probabilities of exceeding an exploitation rate of 0.15 the following year (2013/2014), are presented in Table 5.

The performance of the model's prediction of biomass in the next year was evaluated by comparing predictions from fits to the data up to year $t-1$ (e.g., 2005) to year t (e.g., 2006) with the estimates of biomass from fitting the model to data up to year t (Figure 78). All of the model estimates fall within the 50% credible interval of the prediction from the previous year.

[1]This area has a high incidence of the bryozoan *Flustra foliacea* which may affect gear efficiency.

SPA 5: ANNAPOLIS BASIN

COMMERCIAL FISHERY

The fishery in the Annapolis Basin runs from 1 January to 31 March. In 2012, The Full Bay fleet caught a total of 6 t against a TAC of 10 t (Figure 79).

Year	Avg. 02–06	2006/ 2007	2007/ 2008	2008/ 2009	2009/ 2010	2010/ 2011	2011/ 2012
TAC (t)	14	10	10	10	10	10	10
Landing (t)	10.8	4	7	6	8	9.7	6.0[1]

1. Landings based on quota report as of 6 November 2012.

Catch rates in 2011/2012 were 11.4 kg/hr, a decline from 2010/2011 (19.9 kg/h) and below the long-term median of 18.6 kg/h. Effort in this area has been increasing since 2008/2009 (Figure 80).

SURVEY

The annual survey in this area was discontinued as of 2009 and the sampling effort was redirected to other areas in the Bay of Fundy.

STOCK STATUS AND FORECAST

TAC in this area has been set at 10 t since 1997/1998, except for a few years where it was increased to take advantage of good recruitment. Since 2007, the average annual catch has been 6.8 t and the average catch rate has been 16.0 kg/h. The commercial catch rate is now the fourth lowest since 1997 (6.6 kg/h). The prospects of future recruitment events are unknown without an annual survey.

SPA 6: GRAND MANAN AND SOUTHWEST NEW BRUNSWICK

COMMERCIAL FISHERY

A total of 55.5 t was caught against a TAC of 140 t in SPA 6. Full Bay fleet caught less than 1 t of their 21 t TAC. Mid Bay fleet caught 54.7 t of their allocation of 119 t. A breakdown of landings by subarea for each fleet is in Table 6. Trends in landings and TAC can be seen in Figure 81.

Year	Avg. 02–06	2007	2008	2009	2010	2011	2012
TAC (t)	171	140	140	140	140	140	140
FB: Landing (t)	10	5	7.4	1.3	0.1	0	0.8[1]
MB: Landing (t)	85	64	61	88	102.5	103.9	54.7[1]

1. Landings based on quota report as of 6 November 2012.

Mid Bay catch rates in 2011/2012 decreased in all areas of SPA6 and are below their long-term average catch rates (time series up to and including 2011; Figure 82). The largest decreases were observed for areas 6B (7.0 kg/h vs. average of 10.1 kg/h) and 6D (7.6 kg/h versus

average of 14.4 kg/h). There were not enough catch records from Full Bay fleet to include them in the most recent years in Figure 82 for all areas, but their landings by area is broken out in Table 6.

SURVEY

The survey in SPA 6 took place in August 2012 and consisted of 122 tows in three subareas: 6A (48 tows), 6B[2] (53 tows), and 6C (21 tows). A partial replacement survey design was used in SPA 6 to address the patchiness of scallop distribution in this area. A total of 12, 13, and 6 stations from the 2011 survey were repeated in the 2012 survey in 6A, 6B, and 6C, respectively.

There was a decrease in abundance of commercial scallop in 6A and 6B, and decrease in recruit abundance in 6B (Figure 83, Figure 84). Distribution of recruits and commercial scallops was similar to that seen in 2011 (Figure 85, Figure 86). Area 6C had slight increases in both weight and mean number per tow of commercial scallop (Figure 87). Area 6C had the best meat counts, and the highest meat counts were in 6A (Figure 88). More pre-recruits were observed in 6A this year than in 2011 (Figure 89), less were seen in 6B (Figure 90); 6C had lower numbers of pre-recruits than in the other subareas (Figure 91), and there was a decrease from 2011 to 2012 (Figure 92).

Catches of commercial size scallop were compared for repeated tows in each subarea. In 6A, the repeated tows had a high correlation, both between commercial scallop in both years (Figure 93), and commercial and recruits in 2011 and commercial scallop in 2012 (Figure 94). However, the overall mean number per tow of commercial scallop decreased by half in this area (Table 7), and there was also a decrease from commercial and recruit in 2011 to commercial in 2012, both decreases were significant (Table 7).

In SPA 6B, tows in 2011 had higher numbers of commercial and recruits than were observed in the repeated tows in 2012 (Figure 94) and this change was significant (Table 7). There was a decrease in the mean number of commercial scallop per tow in this area, but the change was not significant (Table 7). In area 6C, repeated tows were highly correlated for both comparisons (Figure 93, Figure 94). Area 6C is the only subarea in SPA 6 which had an increase in both metrics between years (Table 7).

Condition improved in all areas of SPA6, and the greatest improvement was observed in 6C, which had the best condition in the survey time series (Figure 95, Figure 96). Condition in 6B is highest around Duck Island sound (Figure 96).

STOCK STATUS AND FORECAST

In Smith et al. (2012), concern was expressed over declines in survey indices in SPA 6, while noting that commercial catch rates did not appear to indicate similar changes. This year, commercial catch rates have decreased for all areas and are currently lower than their long-term averages further suggesting that biomass in SPA 6 has declined.

[2] Area 6B includes 6D (Duck Island Sound) in the annual survey.

ECOSYSTEM CONSIDERATIONS

Since 2001, commercial groundfish have been recorded as part of the inshore scallop surveys in addition to lobster, squid, and octopus. Survey data on the catches of species other than scallops were reviewed in Smith et al. (2012) to evaluate potential bycatch species in the scallop fishery. There were no fisheries observer trips in the Bay of Fundy scallop fishery in 2012. Refer to Sameoto and Glass (2012) for analysis of discards from the inshore scallop fishery.

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TABLES

Table 1. Total number of tows by survey area

Area	Year										
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
SPA 1, 4 and 5[1]	346	298	266	421	497	384	456	440	376	380	380
SPA 3	111	123	109	162	147	150	151	150	152	160	150
SPA 6	105	102	NA	45	180	169	145	120	102	119	122

1. Survey in SPA 5 discontinued in 2009

Table 2. Decision table for SPA 1A to evaluate 2012/2013 catch levels in terms of expected changes in biomass (%) and probability of decline. Posterior median exploitation rates given in column e. Potential catches in 2013/2014 are evaluated in terms of the posterior probability of exceeding exploitation rate of 0.15.

2012/2013				$Pr(e_{2013/2014} \geq 0.15)$					
Catch (t)	e	% Change	*Pr* (decline)	0.1	0.2	0.3	0.4	0.5	0.6
100	0.07	0.4	0.50	68	101	134	171	213	264
150	0.11	-3.8	0.53	65	97	129	163	204	255
200	0.15	-9.4	0.57	60	90	122	155	193	242
250	0.18	-12.9	0.60	58	88	116	150	188	237
300	0.22	-16.8	0.62	54	81	110	142	180	228
350	0.25	-21.9	0.66	50	77	104	134	169	215

Table 3. Decision table for SPA 1B to evaluate 2012/2013 catch levels in terms of expected changes in biomass (%) and probability of decline. Posterior median exploitation rates given in column e. Potential catches in 2013/2014 are evaluated in terms of the posterior probability of exceeding exploitation rate of 0.15.

2012/2013				$Pr(e_{2013/2014} \geq 0.15)$					
Catch (t)	e	% Change	*Pr* (decline)	0.1	0.2	0.3	0.4	0.5	0.6
100	0.05	15.0	0.41	114	170	226	288	362	450
150	0.07	11.2	0.43	112	167	222	282	352	443
200	0.09	8.1	0.45	108	163	218	277	344	432
250	0.12	4.6	0.47	104	157	211	269	335	421
300	0.14	1.6	0.49	101	152	204	262	328	409
325	0.15	0.1	0.50	100	151	202	260	325	406
350	0.17	-1.8	0.51	98	149	200	254	319	402
400	0.19	-5.0	0.53	93	143	193	247	309	389
450	0.22	-9.1	0.56	92	137	183	235	296	375

Table 4. Decision table for SPA 3 to evaluate 2012/2013 catch levels in terms of expected changes in biomass (%) and probability of decline. Posterior median exploitation rates given in column e. Potential catches in 2013/2014 are evaluated in terms of the posterior probability of exceeding exploitation rate of 0.15.

2012/2013				$Pr(e_{2013/2014} \geq 0.15)$					
Catch (t)	e	% Change	*Pr* (decline)	0.1	0.2	0.3	0.4	0.5	0.6
150	0.12	-0.1	0.50	59	87	117	148	183	230
175	0.15	- 2.3	0.51	57	86	114	145	180	228
200	0.16	-4.1	0.53	56	82	109	140	177	223
225	0.19	-6.6	0.55	54	81	109	139	176	220
250	0.21	-9.5	0.57	52	78	105	135	170	213
275	0.23	-12.9	0.59	51	76	103	131	165	206
300	0.25	-16.4	0.62	48	73	97	125	158	200
325	0.27	-17.8	0.64	47	71	95	122	153	194
350	0.30	-22.6	0.66	45	68	90	116	145	184

Table 5. Decision table for SPA 4 to evaluate 2012/2013 catch levels in terms of expected changes in biomass (%) and probability of decline. Posterior median exploitation rates given in column e. Potential catches in 2013/2014 are evaluated in terms of the posterior probability of exceeding exploitation rate of 0.15.

2012/2013				$Pr(e_{2013/2014} \geq 0.15)$					
Catch (t)	e	% Change	*Pr* (decline)	0.1	0.2	0.3	0.4	0.5	0.6
100	0.14	-12.2	0.60	35	50	65	81	99	123
110	0.15	-12.7	0.60	35	50	65	80	98	121
120	0.16	-14.6	0.62	35	50	64	79	97	118
140	0.19	-16.7	0.64	33	47	62	76	94	116
160	0.22	-20.4	0.67	32	46	59	74	90	113
180	0.24	-23.2	0.69	30	43	57	71	88	109
200	0.27	-25.6	0.71	29	42	55	69	85	107

Table 6. Catch (meat, tons) by fleet and subarea for SPA 6. Landings current as of 6 November 2012.

	Catch (meats, t)								
Subarea	2004	2005	2006	2007	2008	2009	2010	2011	2012
				Full Bay					
TAC	50	25	25	35	21	21	21	21	21
6A	1.1	0.3	0.9	2.3	1.7	0.3	0.07	0	0.31
6B	0.6	3.2	1.7	1.7	1.9	0.8	0	0	0
6C	3.74	0.2	0.3	0.1	2.7	0.2	0	0	0.33
6D	2.8	1.2	1.4	0.8	1.1	0.05	0	0	0.18
Total	8.1	4.9	4.4	4.9	7.4	1.3	0.07	0	0.82
				Mid Bay					
TAC	145	145	75	105	119	119	119	119	119
6A	13.1	38.0	25.2	22.2	15.8	25.5	32.3	23.9	11.4
6B	14.5	18.1	23.7	11.3	10.8	23.1	23.2	26.5	13.8
6C	23.9	16.7	19.8	23.8	27.6	34.8	46.7	46.5	24.5
6D	22.4	7.9	18.0	6.7	6.3	5.4	0.3	7.0	5.1
Total	74.0	80.7	86.7	64.0	60.6	88.8	102.5	103.9	54.7

Table 7. Sampling with partial replacement estimates of the mean number per tow, difference between mean number per tow for 2011 and 2012 and the standard error (SE) of the difference for SPA 6. Test statistic evaluated using a Student's t distribution.

	Mean no./tow				Test-statistic
Area	2011	2012	Difference	SE (Difference)	(p value)
			Commercial size in 2011		
6A	86.21	46.62	-39.59	11.38	-3.48 (p<001)
6B	52.84	44.65	-8.19	8.92	-0.92 (p=0.4)
6C	10.5	16.37	+5.87	6.24	0.94 (p=35)
			Commercial + recruits in 2011		
6A	98.73	42.66	-56.07	13.27	-4.27(p<001)
6B	67.06	44.19	-22.88	9.95	-2.29 (p=0.02)
6C	12.66	17.46	+4.8	5.89	0.81 (p=0.4)

FIGURES

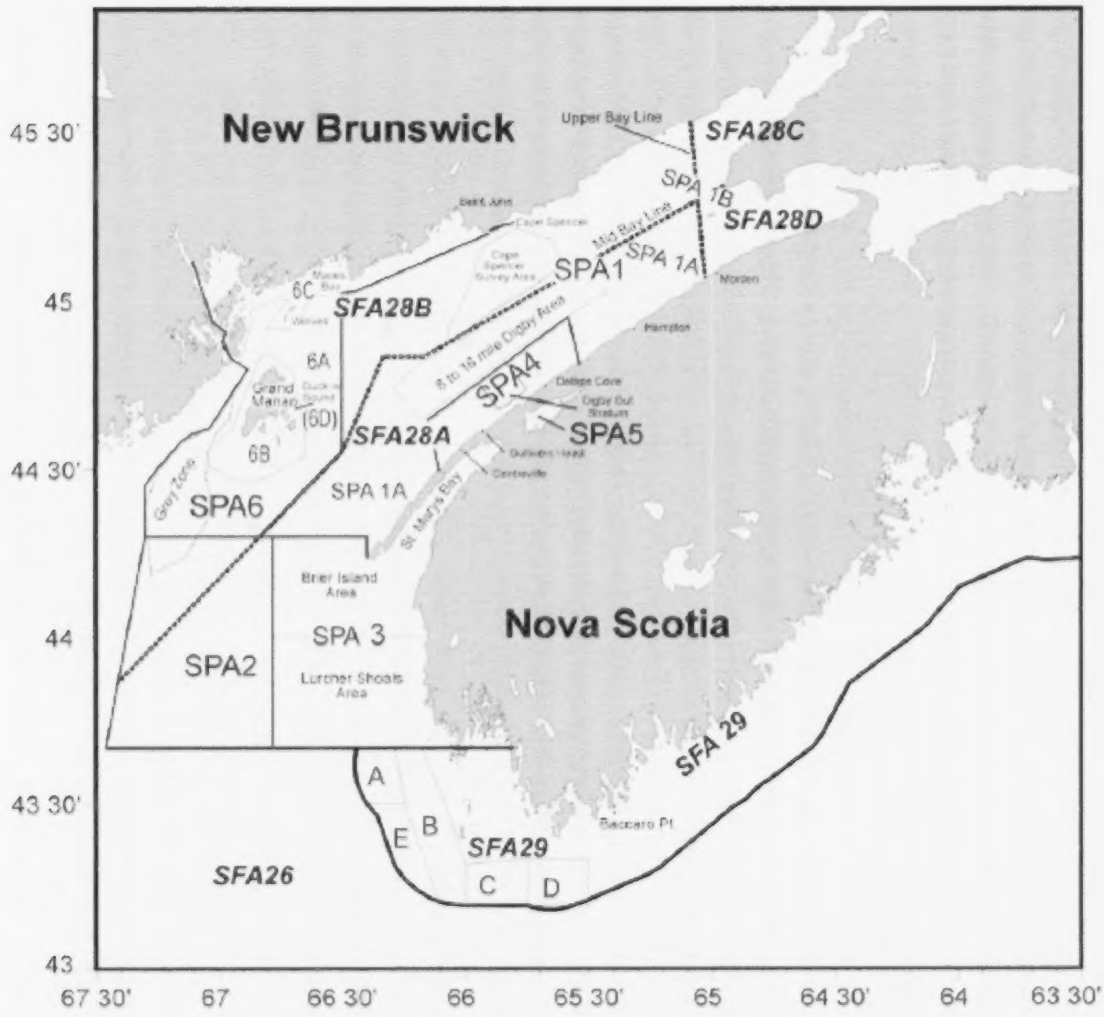

Figure 1. Scallop Production Areas (SPA) and Scallop Fishing Areas (SFA) in the Bay of Fundy.

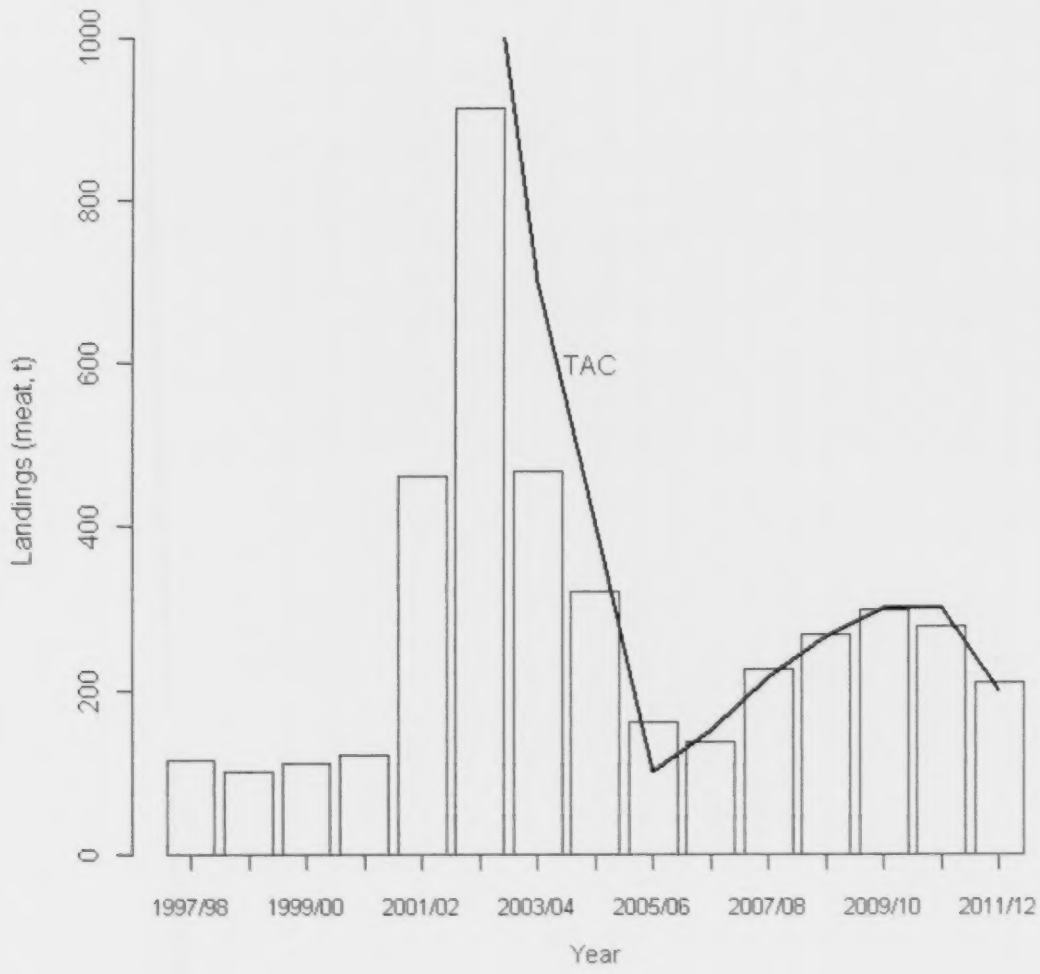

Figure 2. SPA 1A landings (meat, tons) by the Full Bay fleet.

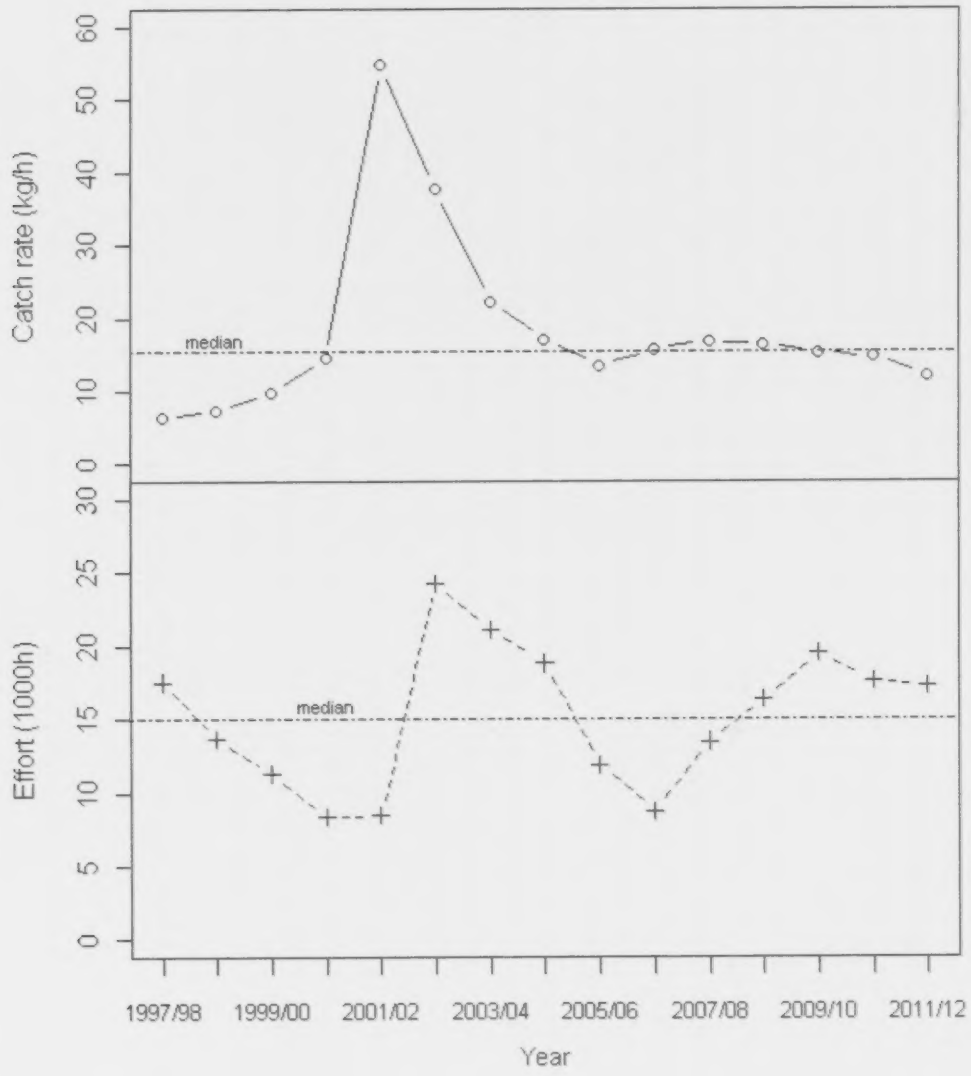

Figure 3. SPA 1A trends in catch rate (kg/h) and effort (1000h) for Full Bay fleet. Median catch rate from 1995/1996 to 2010/2011 indicated.

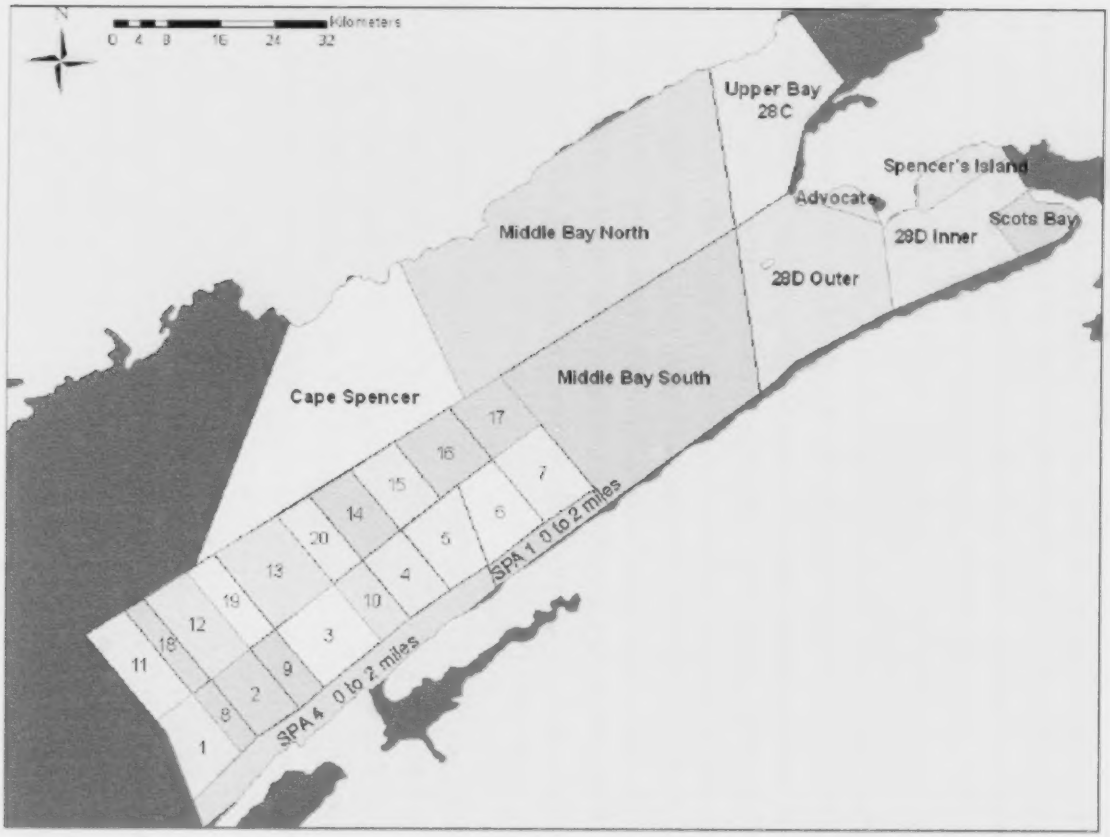

Figure 4. Bay of Fundy scallop survey strata.

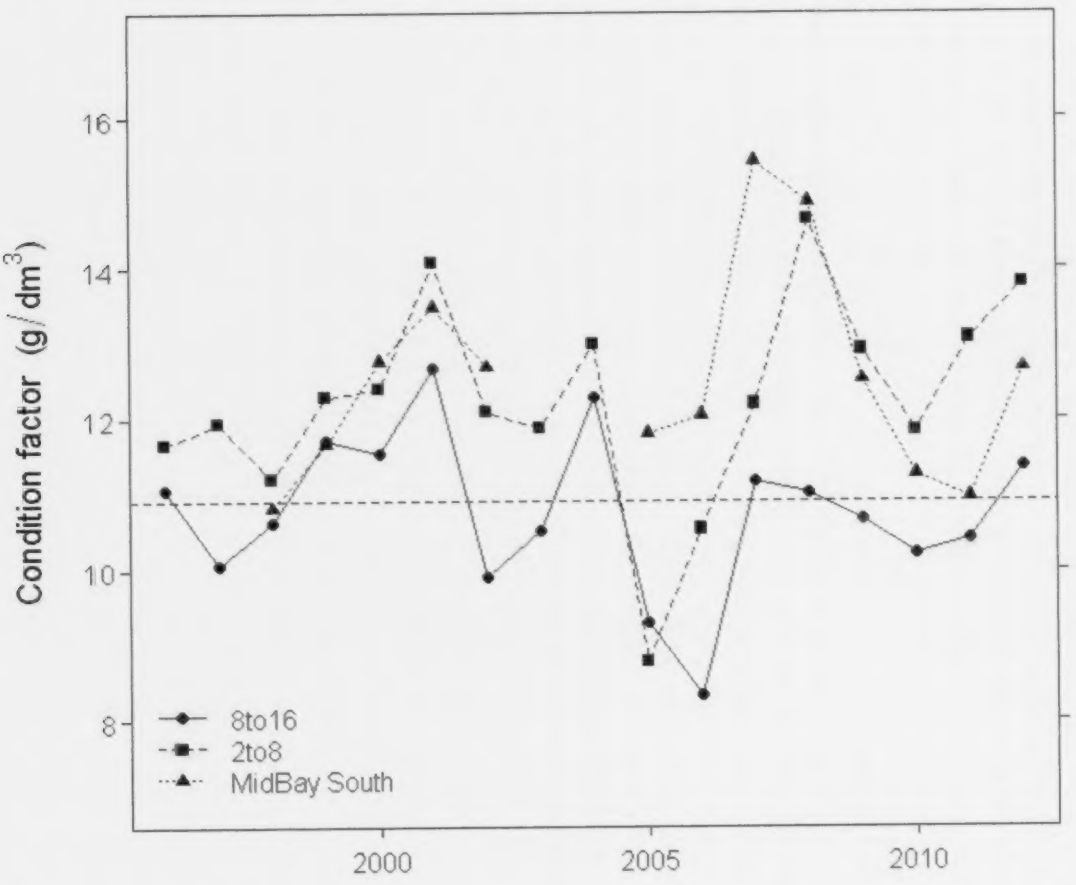

Figure 5. SPA 1A trend in condition factor (g/dm^3) from the annual survey.

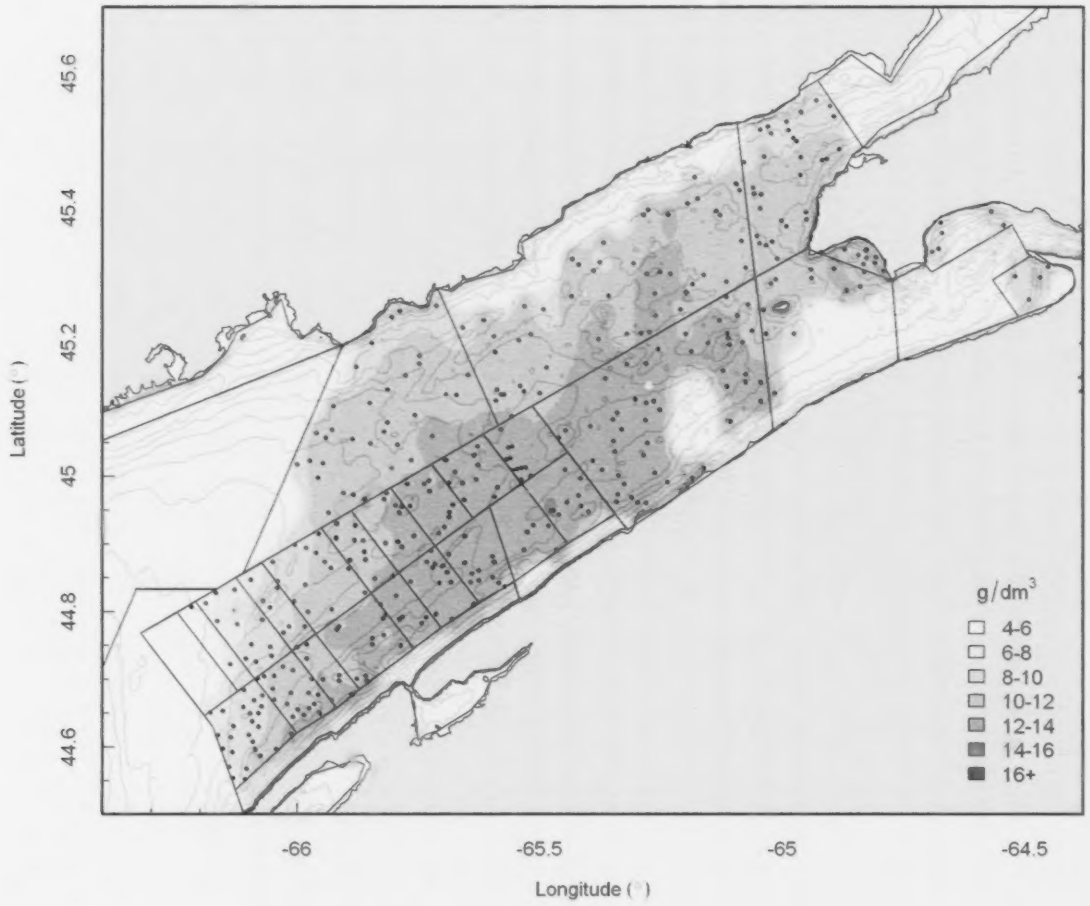

Figure 6. Spatial distribution of condition factor (g/dm^3) from the 2012 survey for the Bay of Fundy.

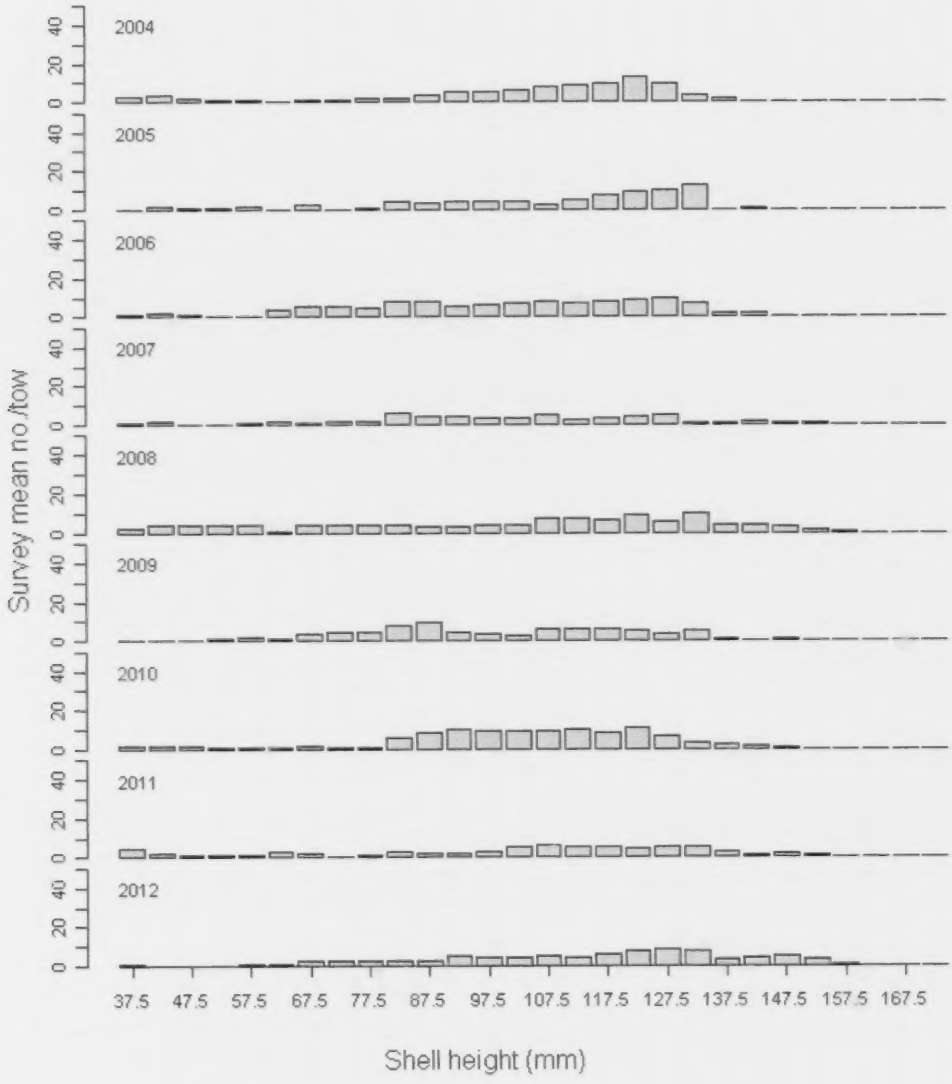

Figure 7. Scallop survey shell height frequencies (mean number/tow) from the 2 to 8 mile zone of SPA 1A.

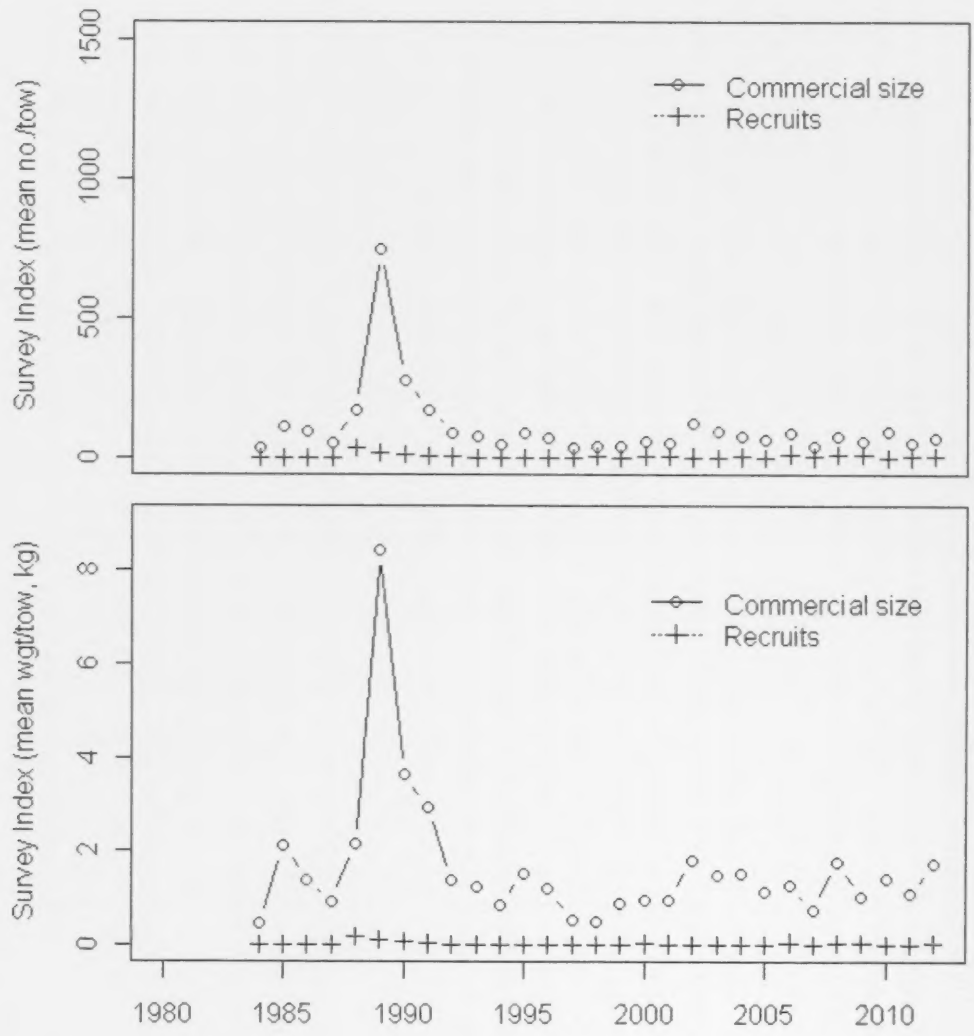

Figure 8. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for the 2 to 8 mile zone of SPA 1A.

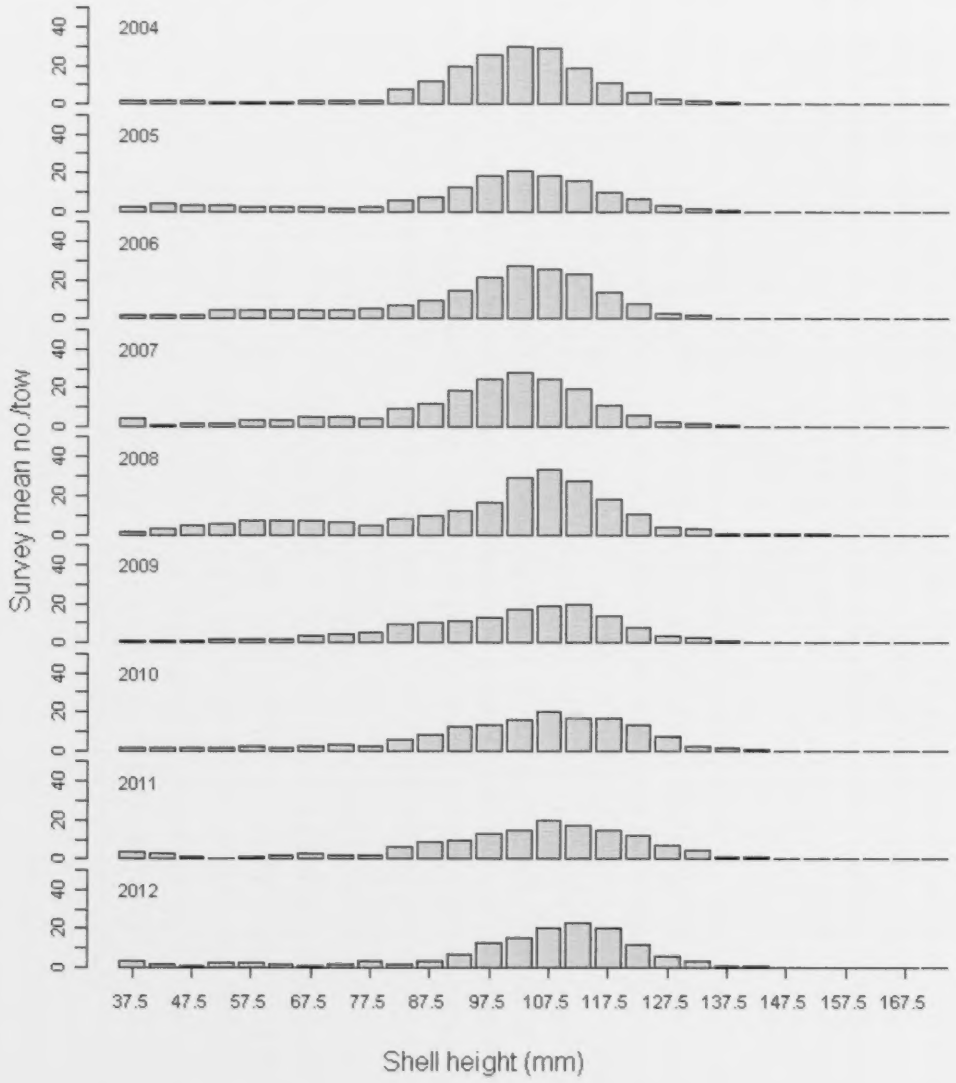

Figure 9. Scallop survey shell height frequencies (mean number/tow) from the 8 to 16 mile zone of SPA 1A.

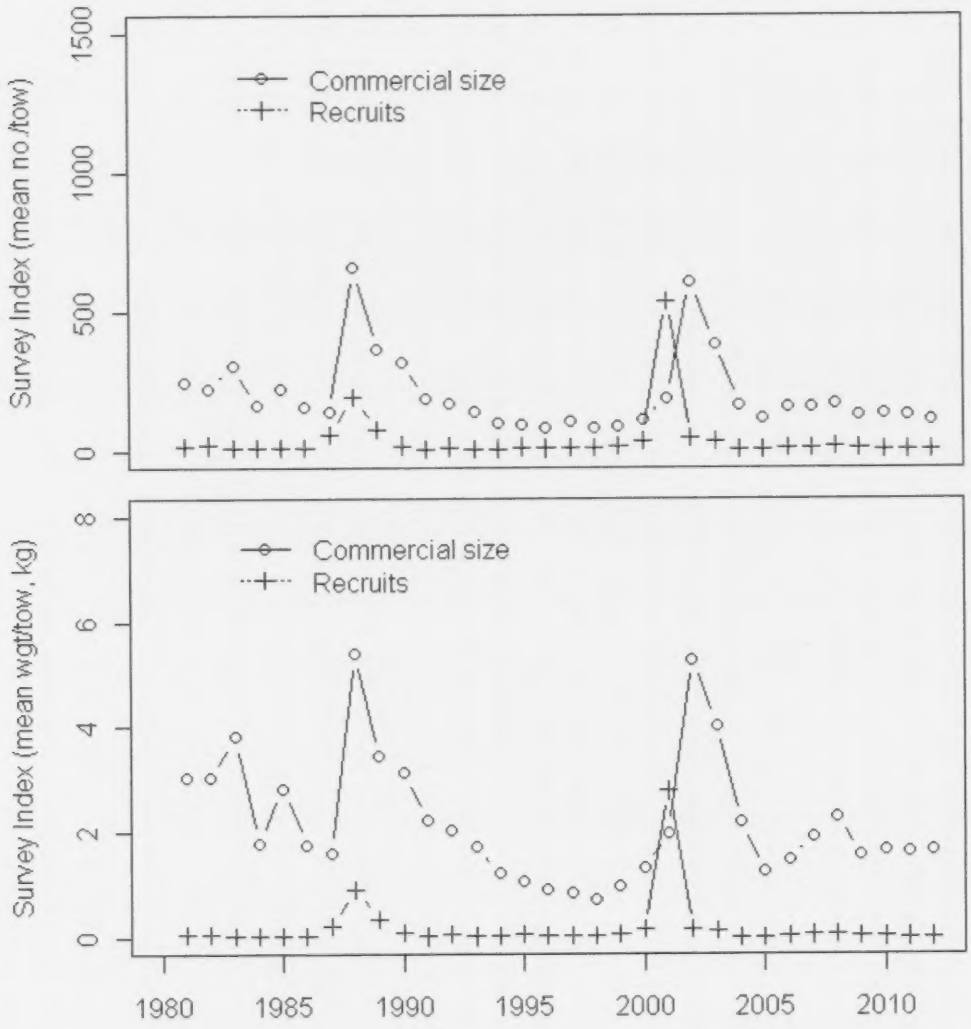

Figure 10. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for the 8 to 16 mile zone of SPA 1A.

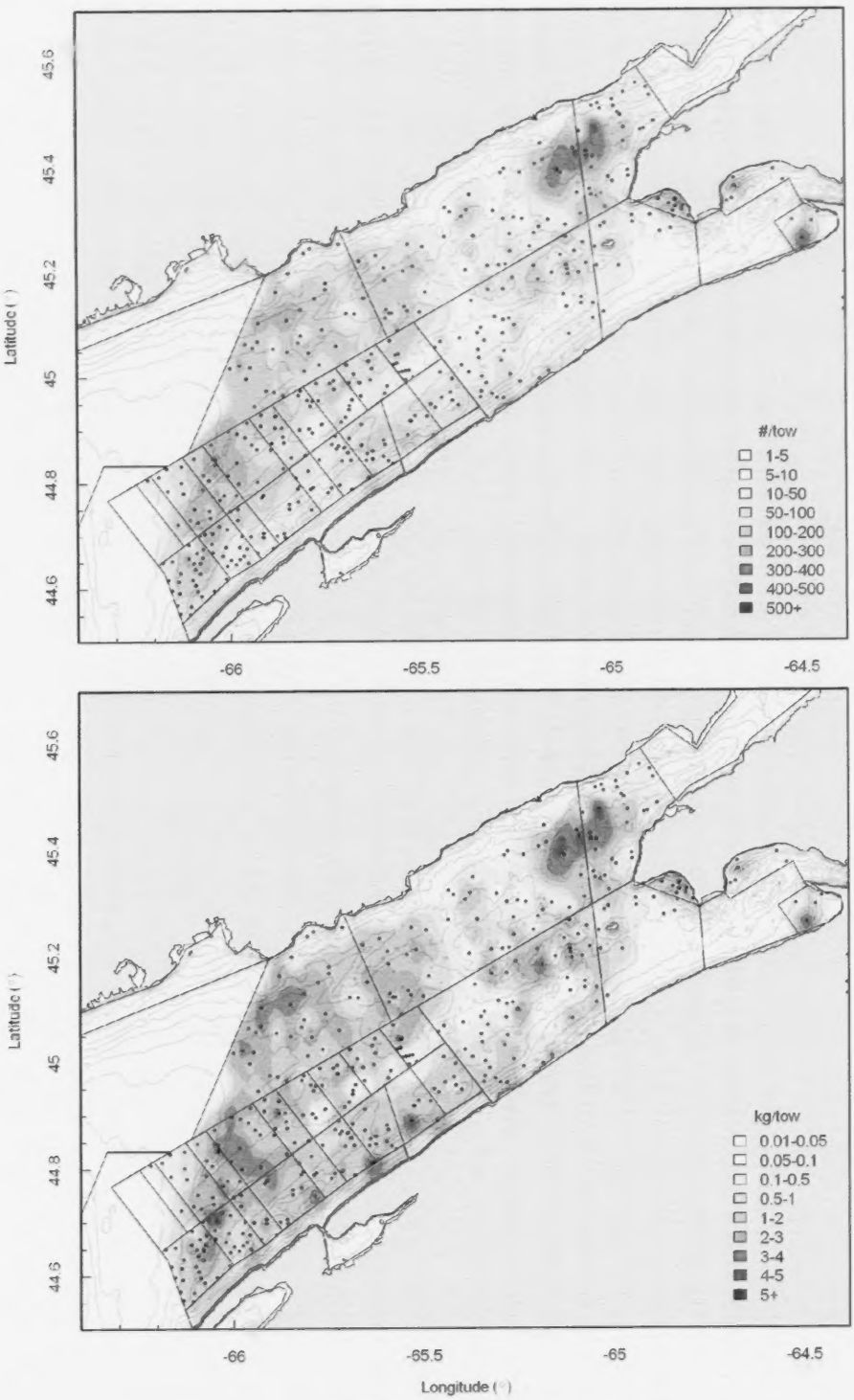

Figure 11. Spatial density of number/tow (upper) and kg/tow (lower) of commercial scallop (≥80 mm) from the 2012 survey for the Bay of Fundy.

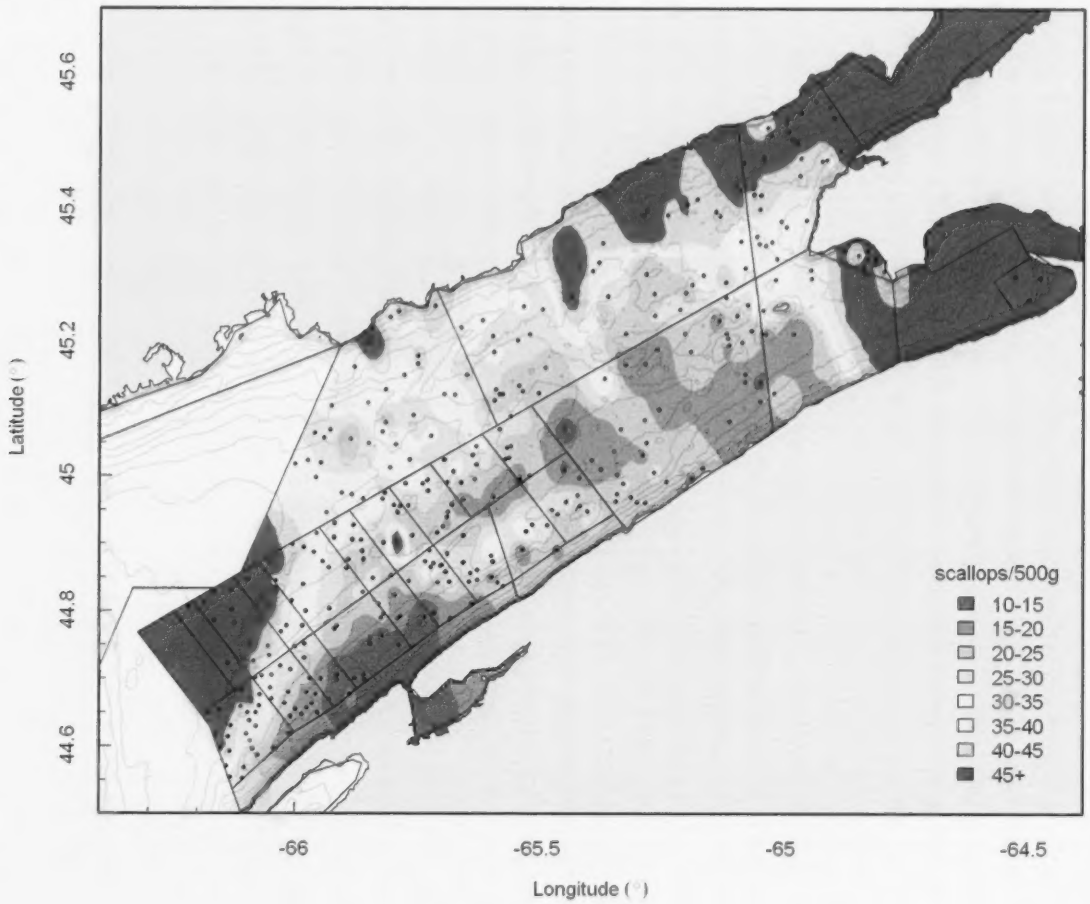

Figure 12. Spatial distribution of meat count (scallops/500 g) from the 2012 survey for the Bay of Fundy.

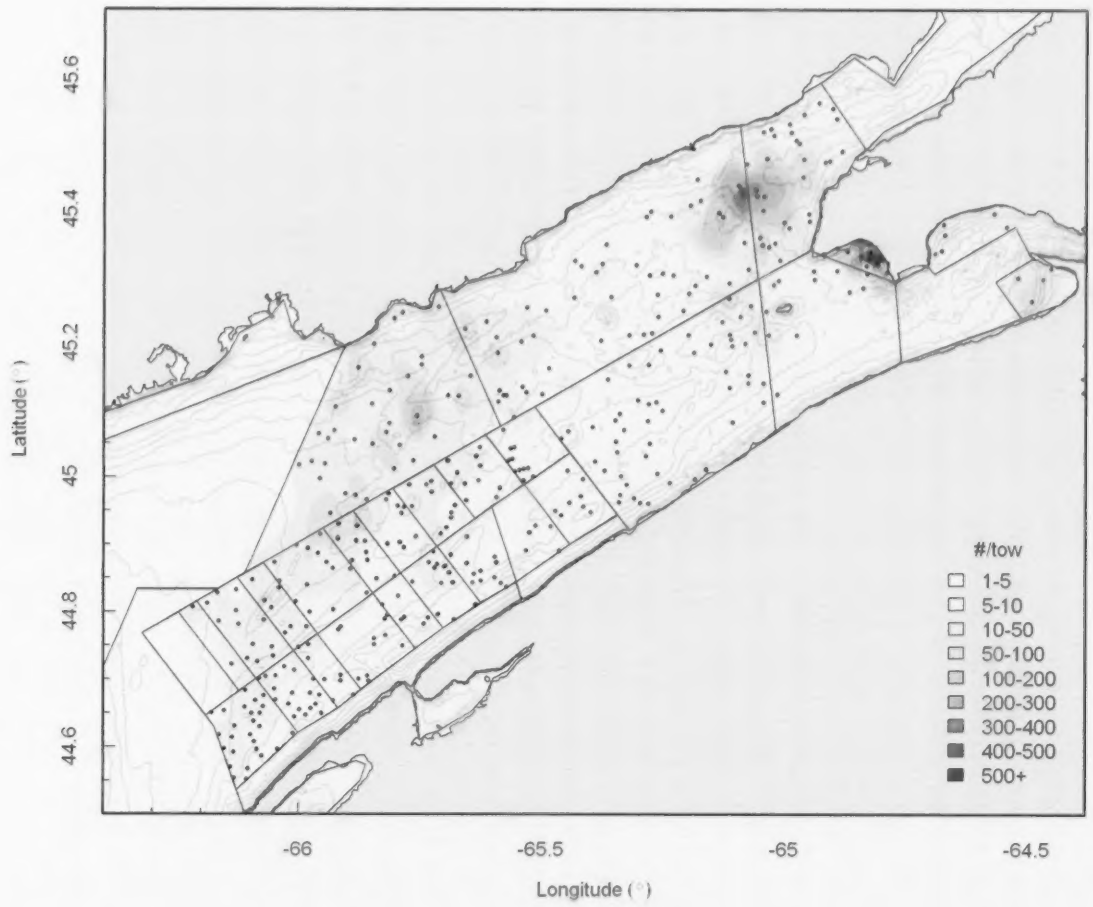

Figure 13. Spatial density (number/tow) of pre-recruit scallop (<65 mm) from the 2012 survey for the Bay of Fundy.

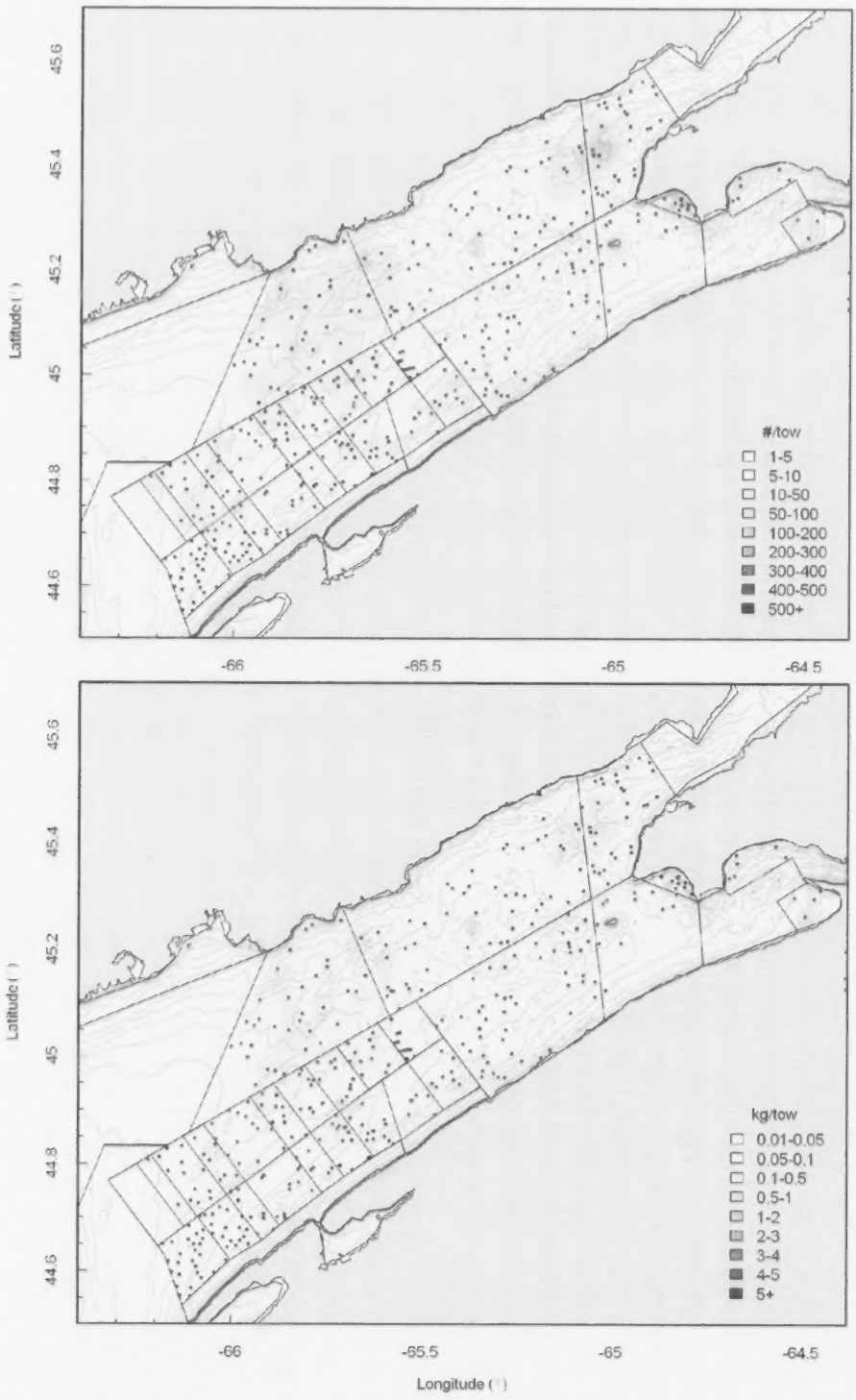

Figure 14. Spatial density number/tow (upper) and kg/tow (lower) of recruit scallop (65-79 mm) from the 2012 survey for the Bay of Fundy.

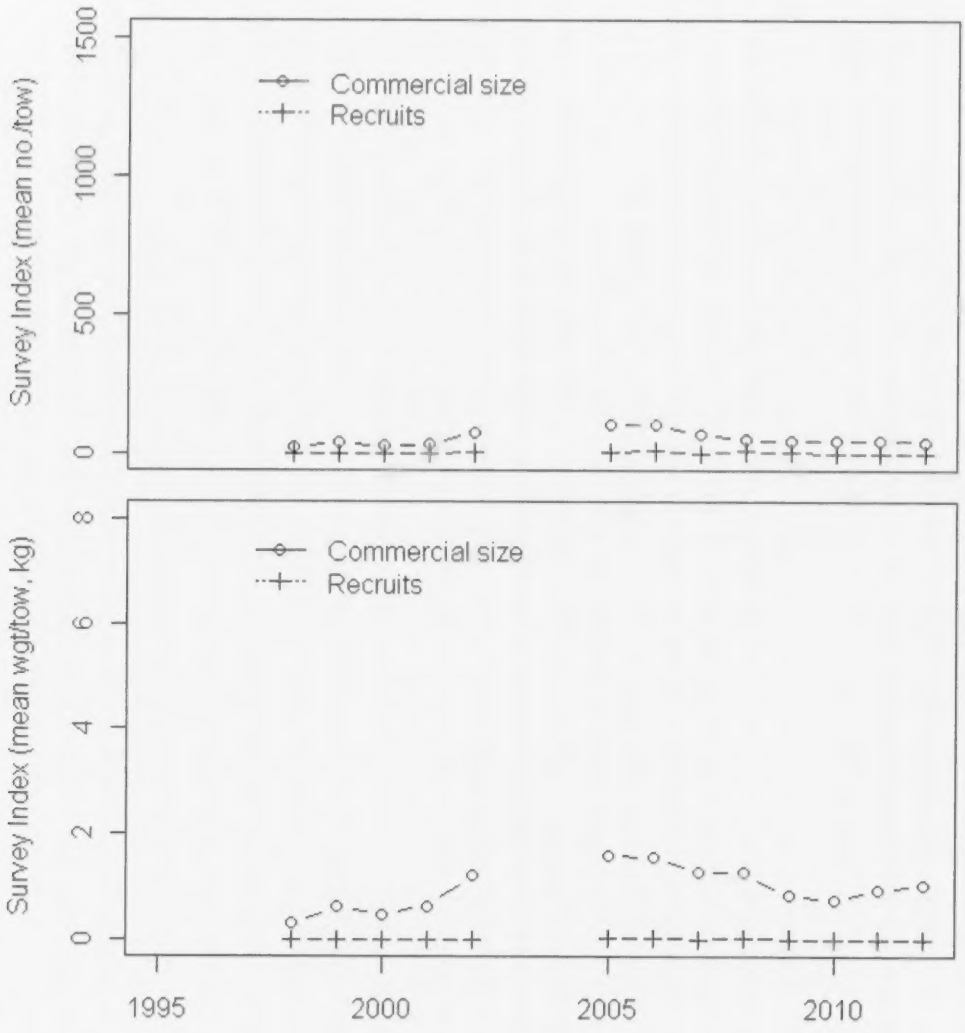

Figure 15. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for the Middle Bay South zone of SPA 1A.

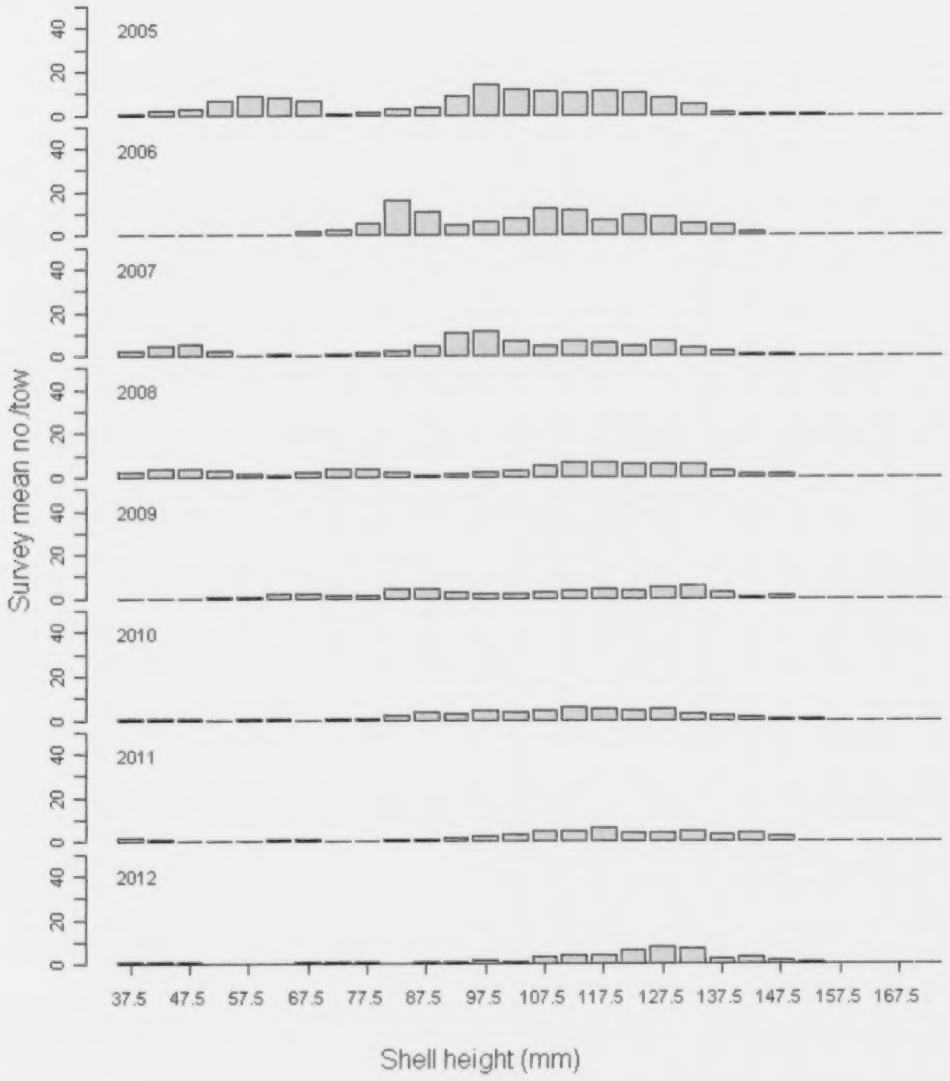

Figure 16. Scallop survey shell height frequencies (mean number/tow) from the Middle Bay South zone of SPA 1A.

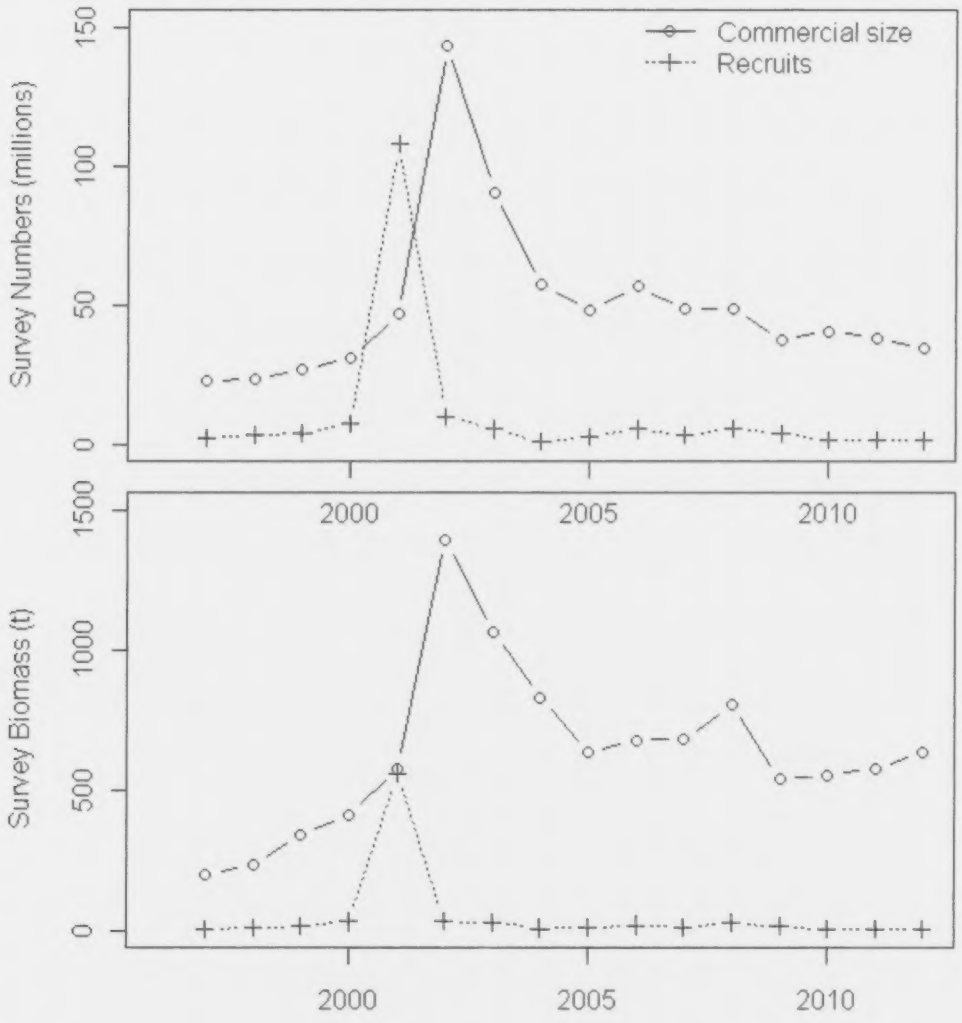

Figure 17. SPA 1A population abundance (upper) and biomass (lower) for commercial (≥80 mm) and recruit (65-79 mm) scallops.

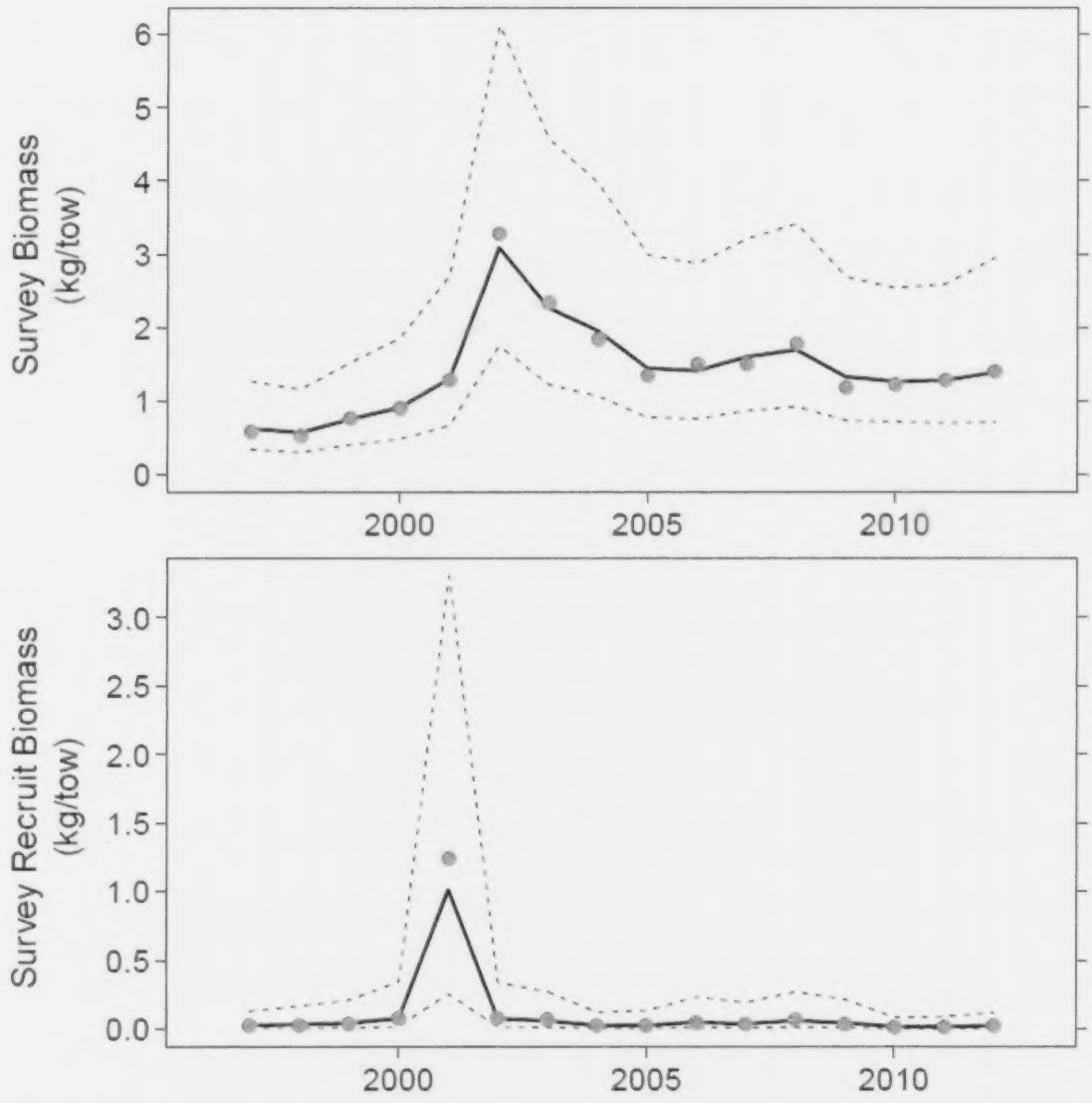

Figure 18. Posterior median fit to the survey series for commercial size and recruit size scallops. Bayesian state-space delay-difference model for scallops in SPA 1A.

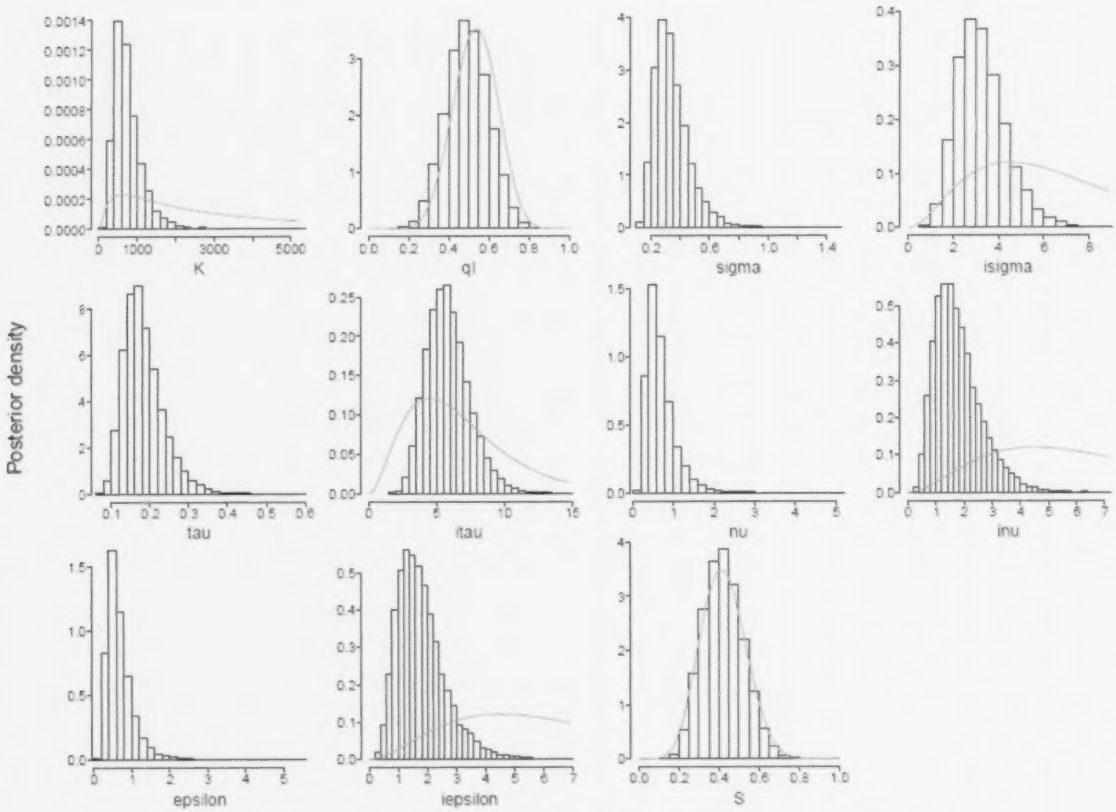

Figure 19. Comparison of prior and posterior densities. Bayesian state-space delay-difference model for scallops in SPA 1A.

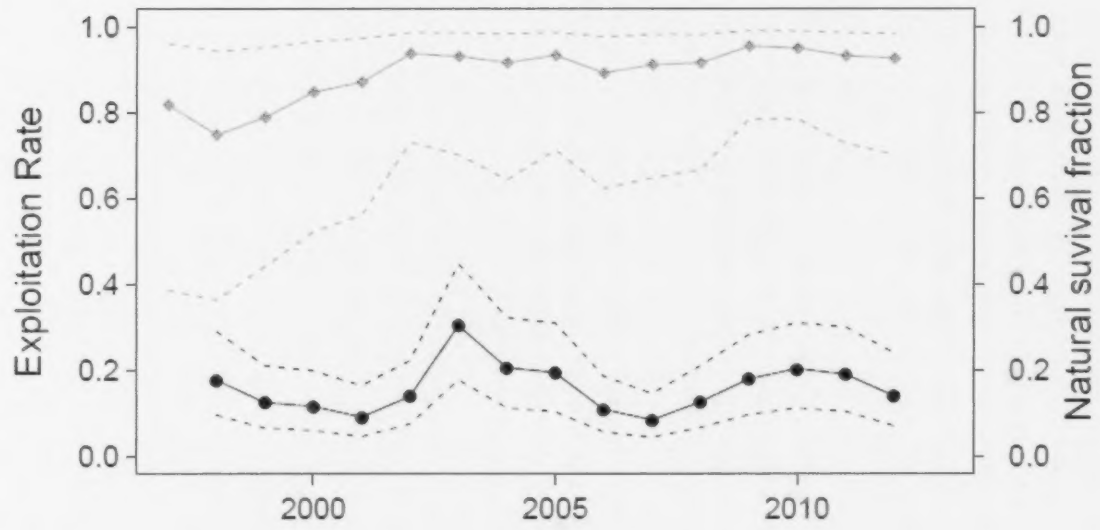

Figure 20. Annual trends in exploitation (black line, circles) and survival estimates ($exp(-m)$, where m is natural mortality; grey line, squares). Bayesian state-space delay-difference model for scallops in SPA 1A.

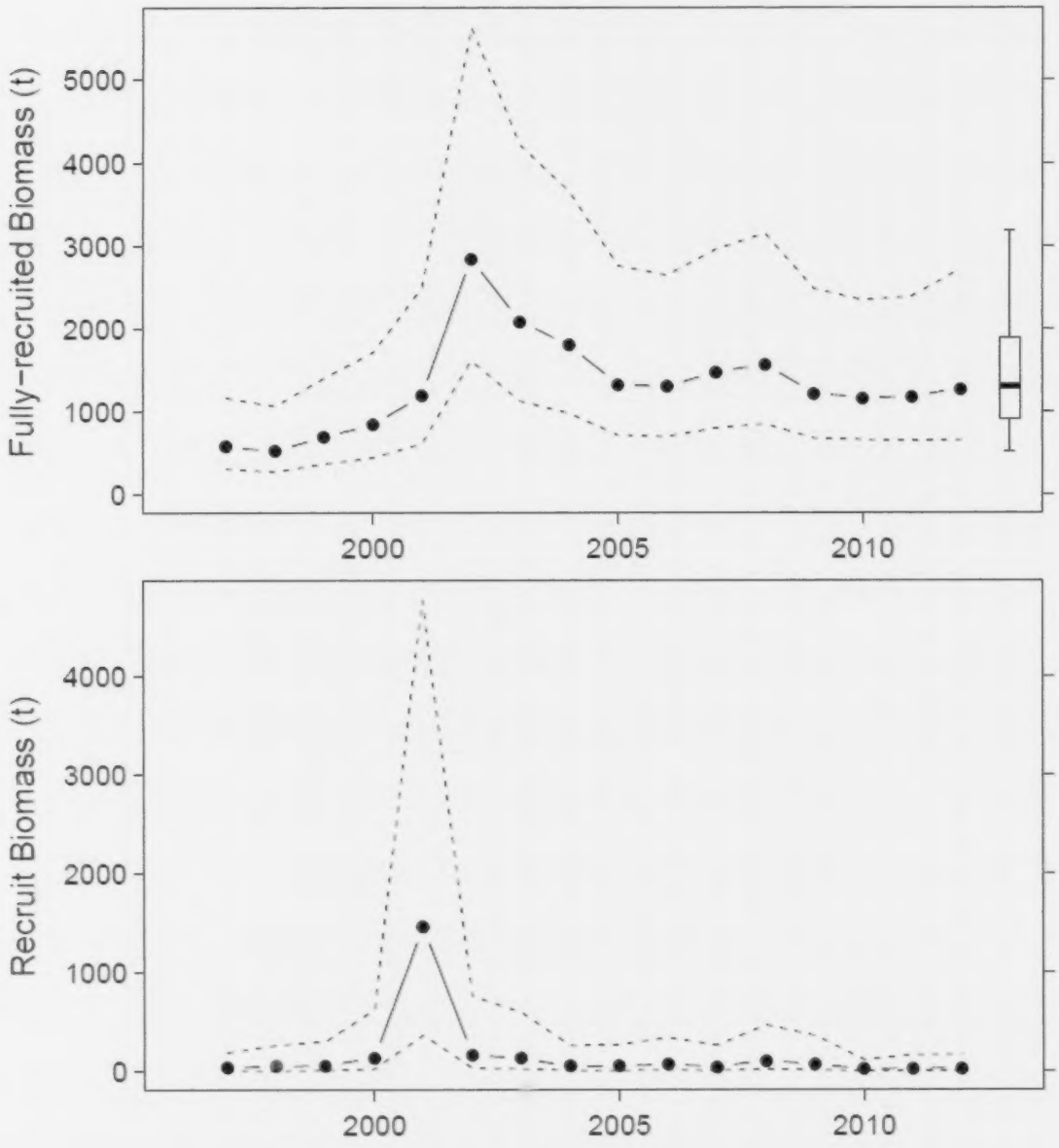

Figure 21. Biomass estimates for fully recruited scallops from the delay-difference model fit to the SPA 1A survey and commercial data. Dashed lines are the upper and lower 95% credible limits on the estimates. The predicted commercial size biomass for 2013, assuming the interim TAC (100 t), is displayed as a box plot with median, 50% credible limits (box) and 80% credible limits (whiskers).

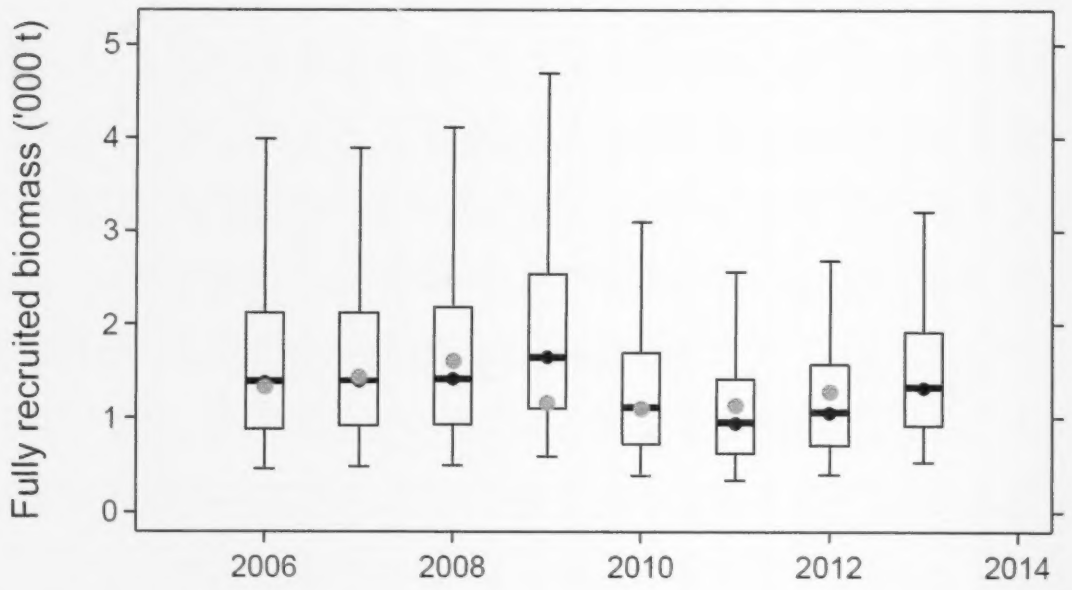

Figure 22. Evaluation of the model projection performance. Box and whisker plots summarize posterior distribution of commercial size biomass in year t based on model fit to year t-1 (e.g., 2006 prediction based on data up to 2005). Red dot represents the estimate of the biomass in year t using data up to and including year t. Bayesian state-space delay-difference model for scallops in SPA 1A.

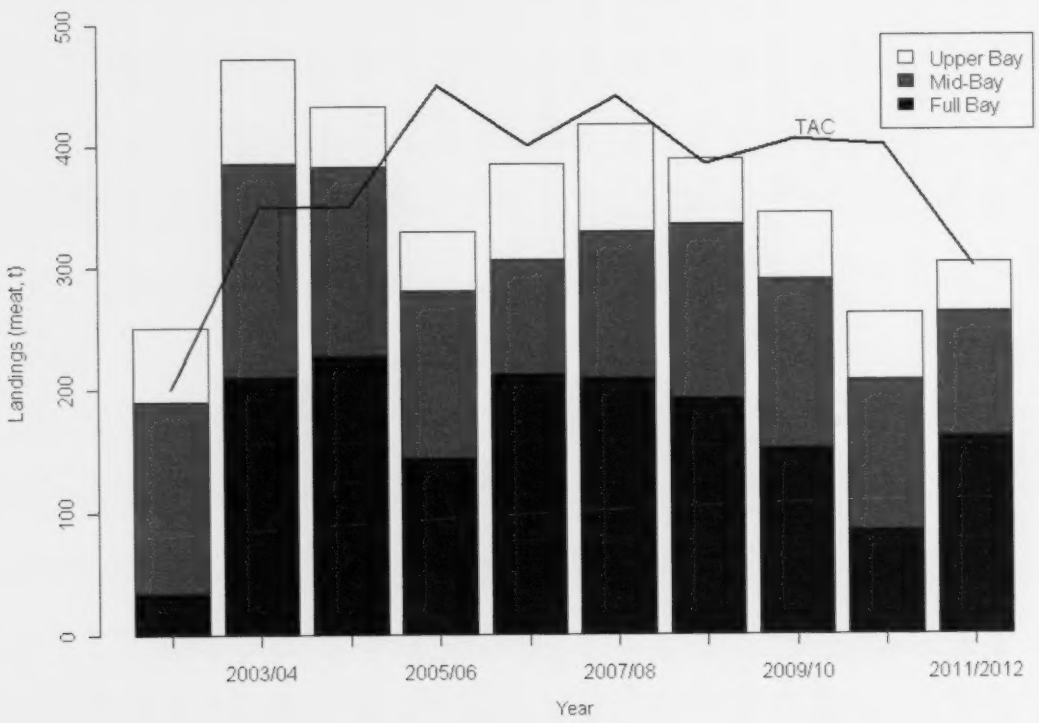

Figure 23. SPA 1B landings (meat, tons) by each fleet.

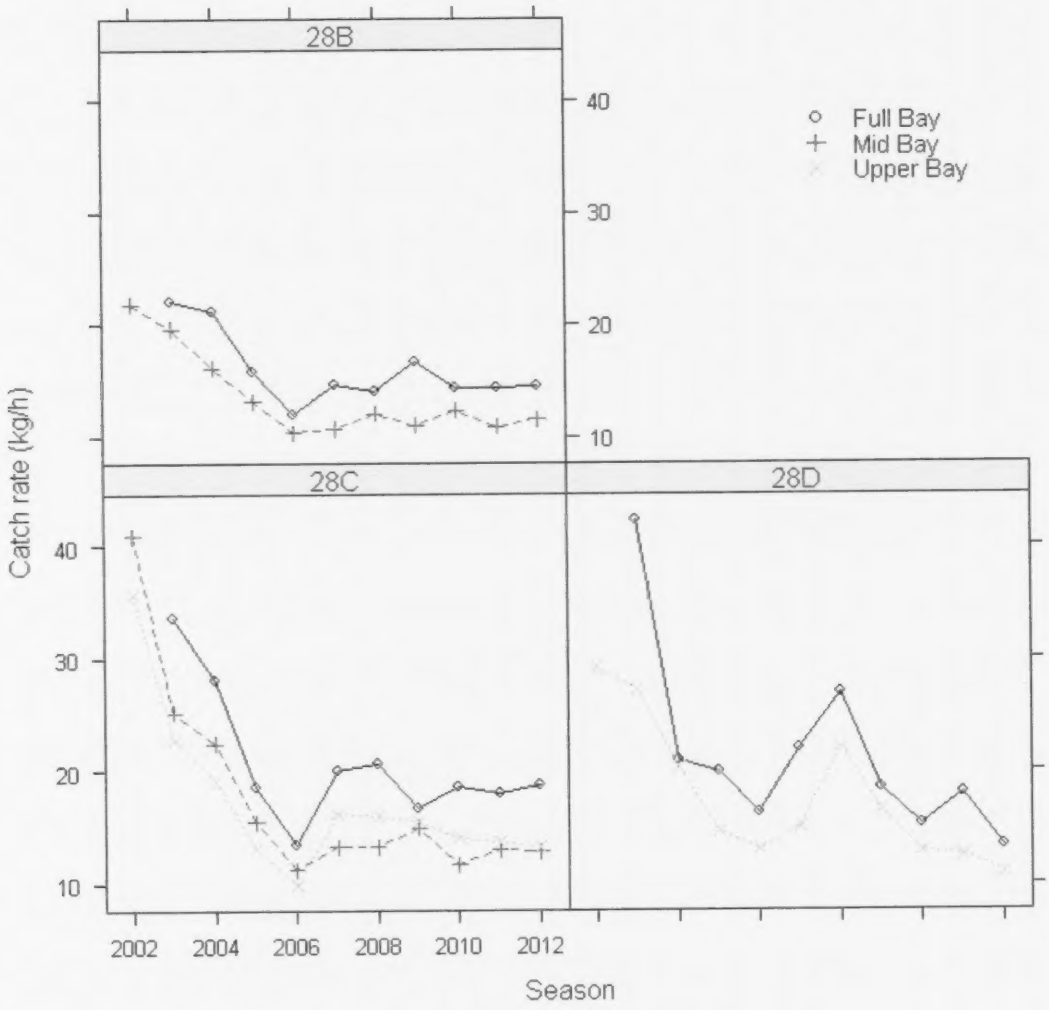

Figure 24. SPA 1B trends in catch rate (kg/h) in each subarea for each fleet.

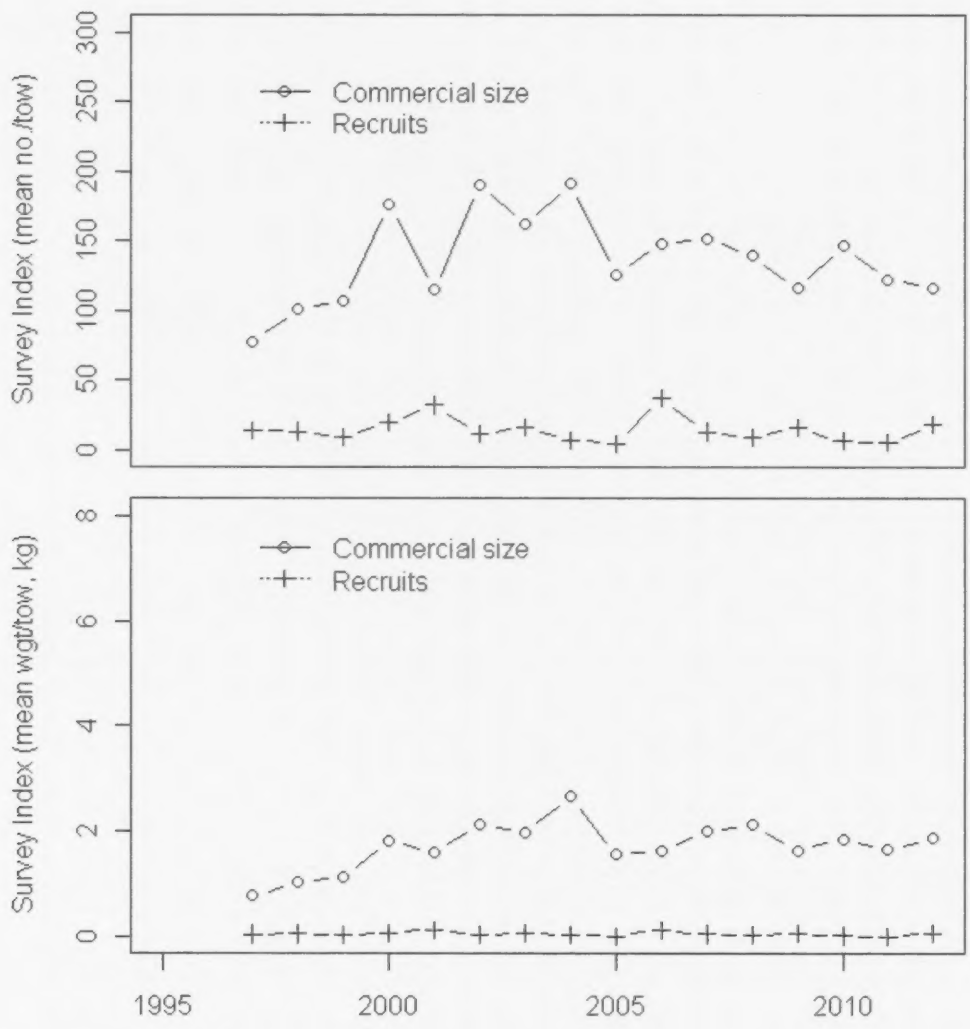

Figure 25. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for the Cape Spencer zone of SPA 1B.

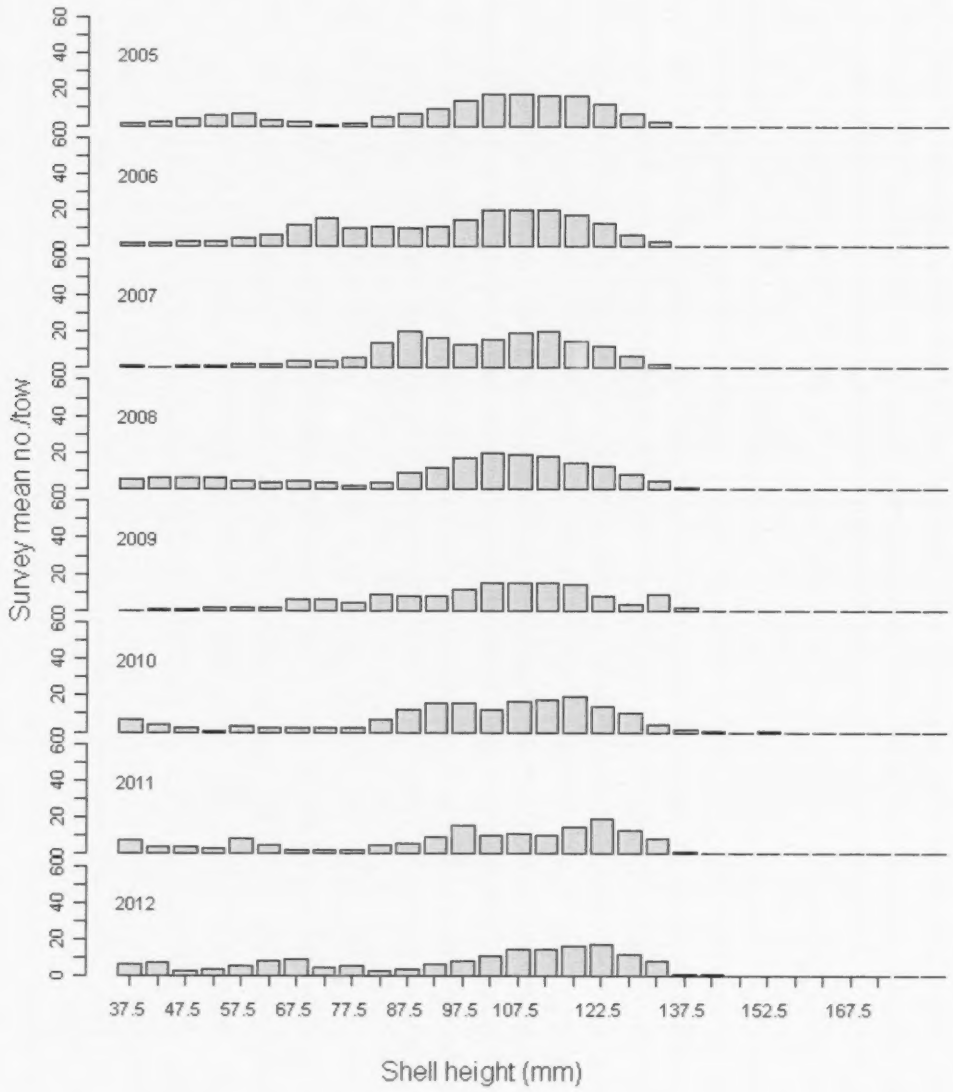

Figure 26. Scallop survey shell height frequencies (mean number/tow) for the Cape Spencer zone of SPA 1B.

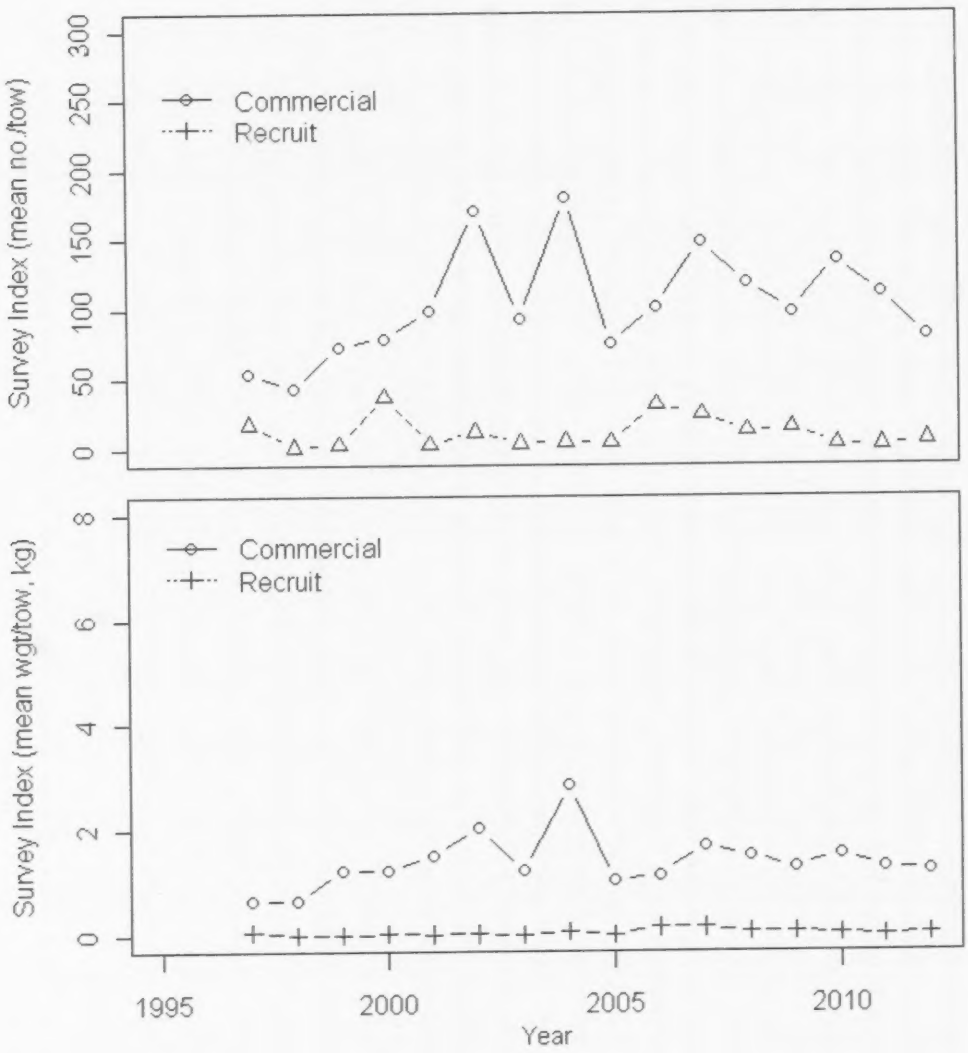

Figure 27. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for the Middle Bay North zone of SPA 1B.

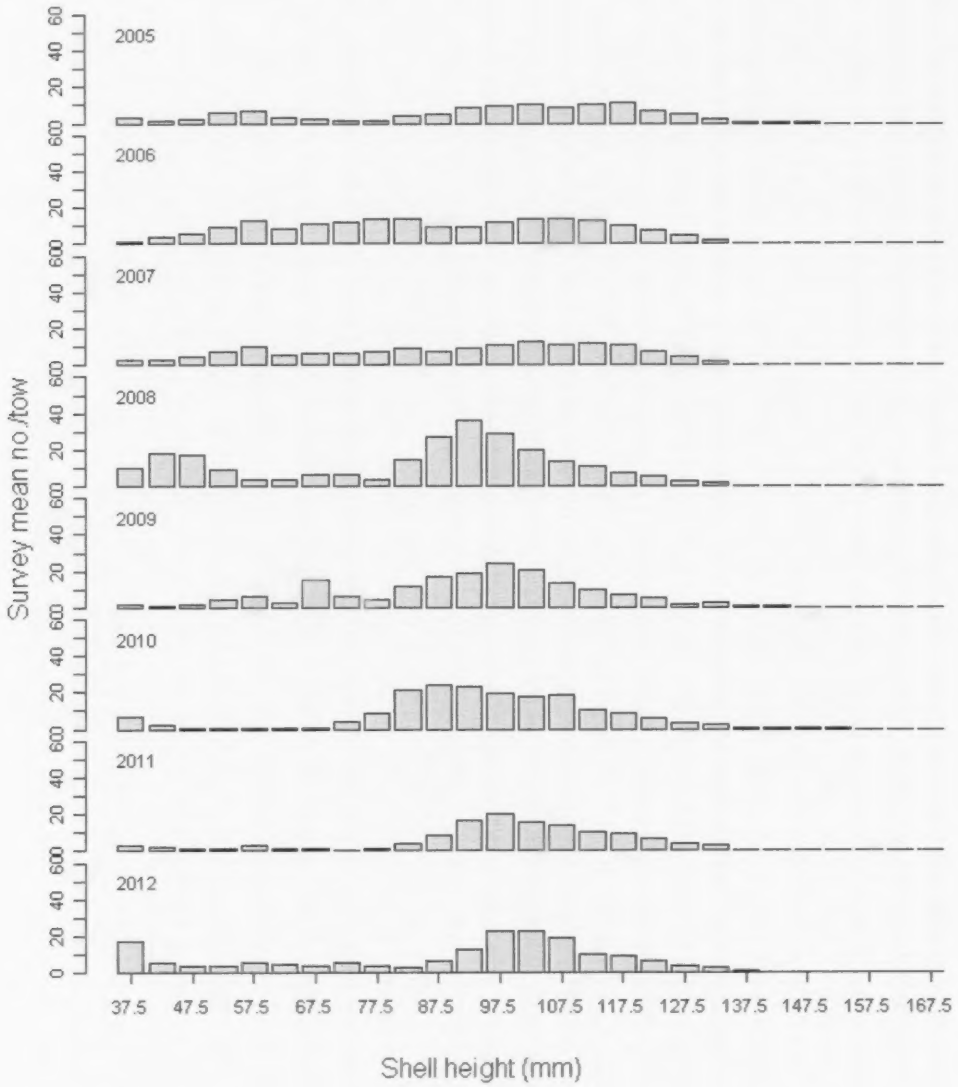

Figure 28. Scallop survey shell height frequencies (mean number/tow) for the Middle Bay North zone of SPA 1B.

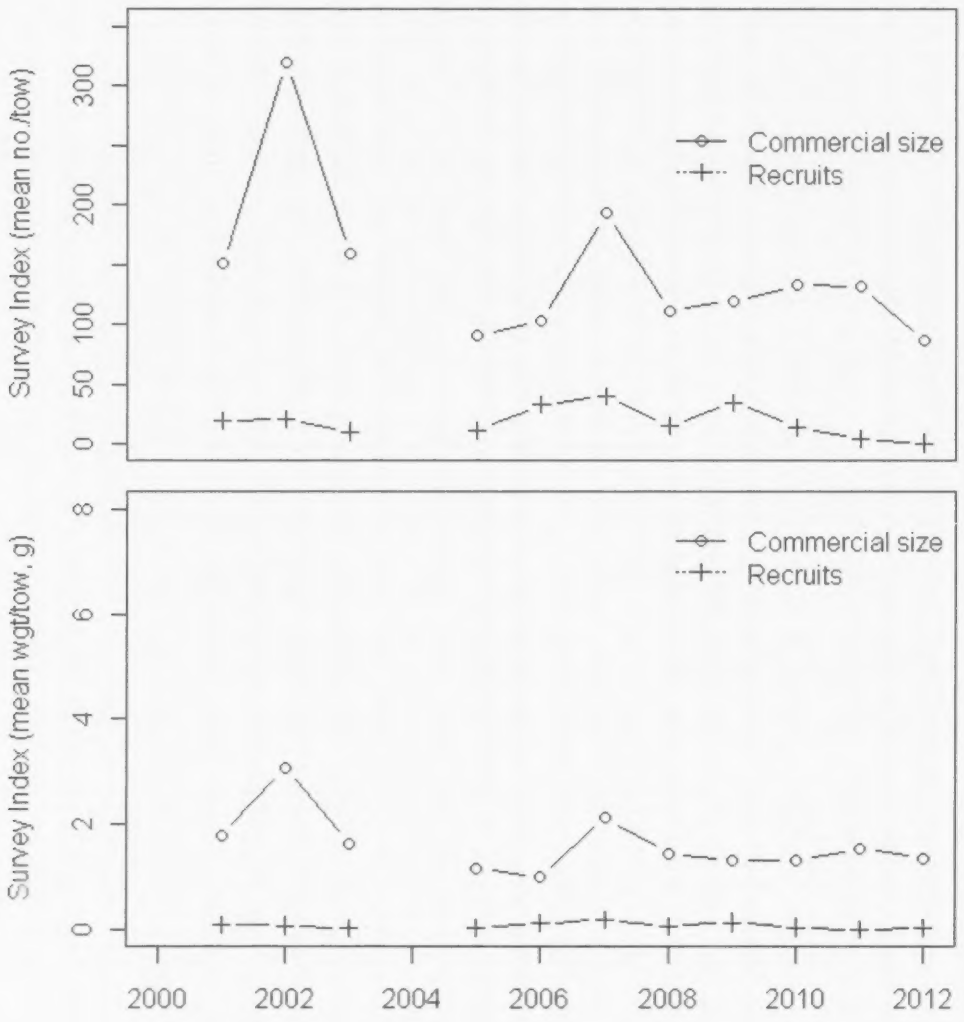

Figure 29. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for the 28C (Upper) zone of SPA 1B.

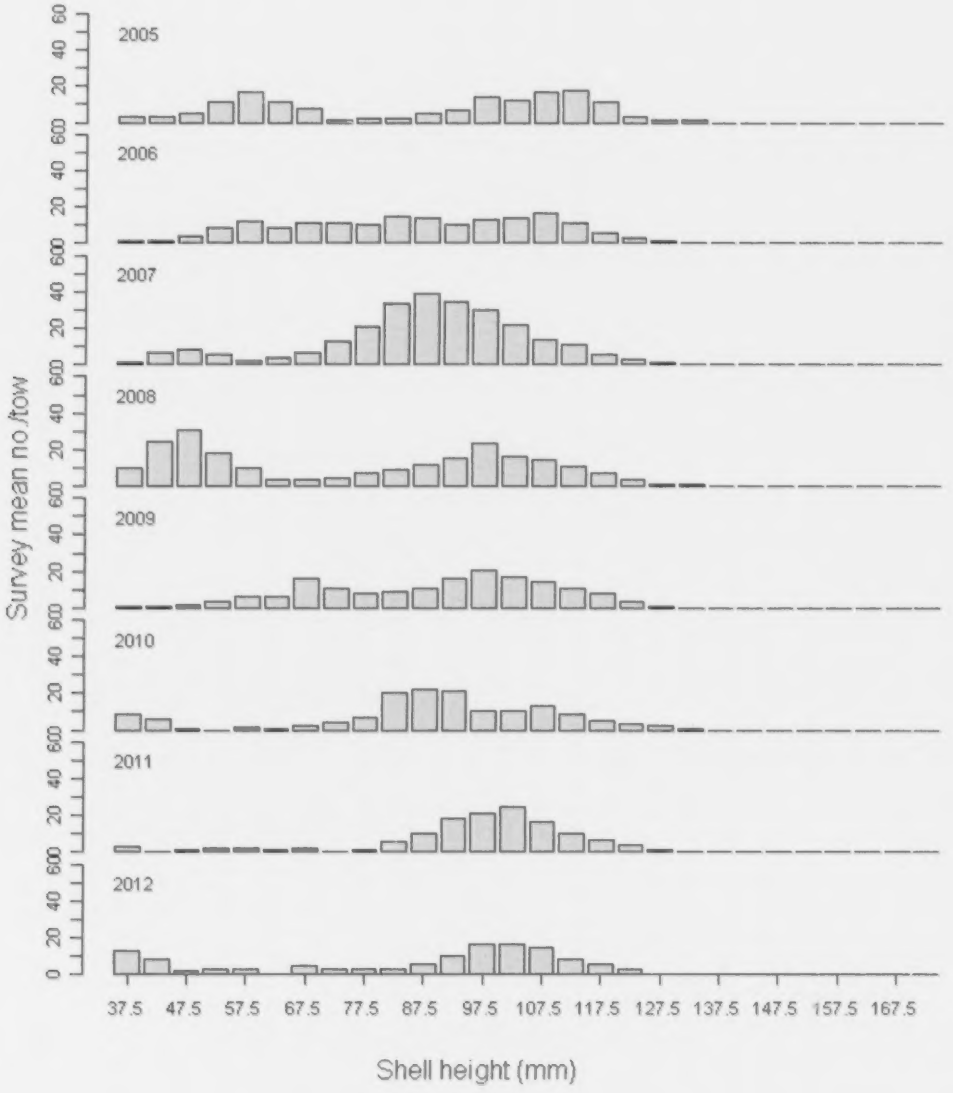

Figure 30. Scallop survey shell height frequencies (mean number/tow) for the 28C (Upper) zone of SPA 1B.

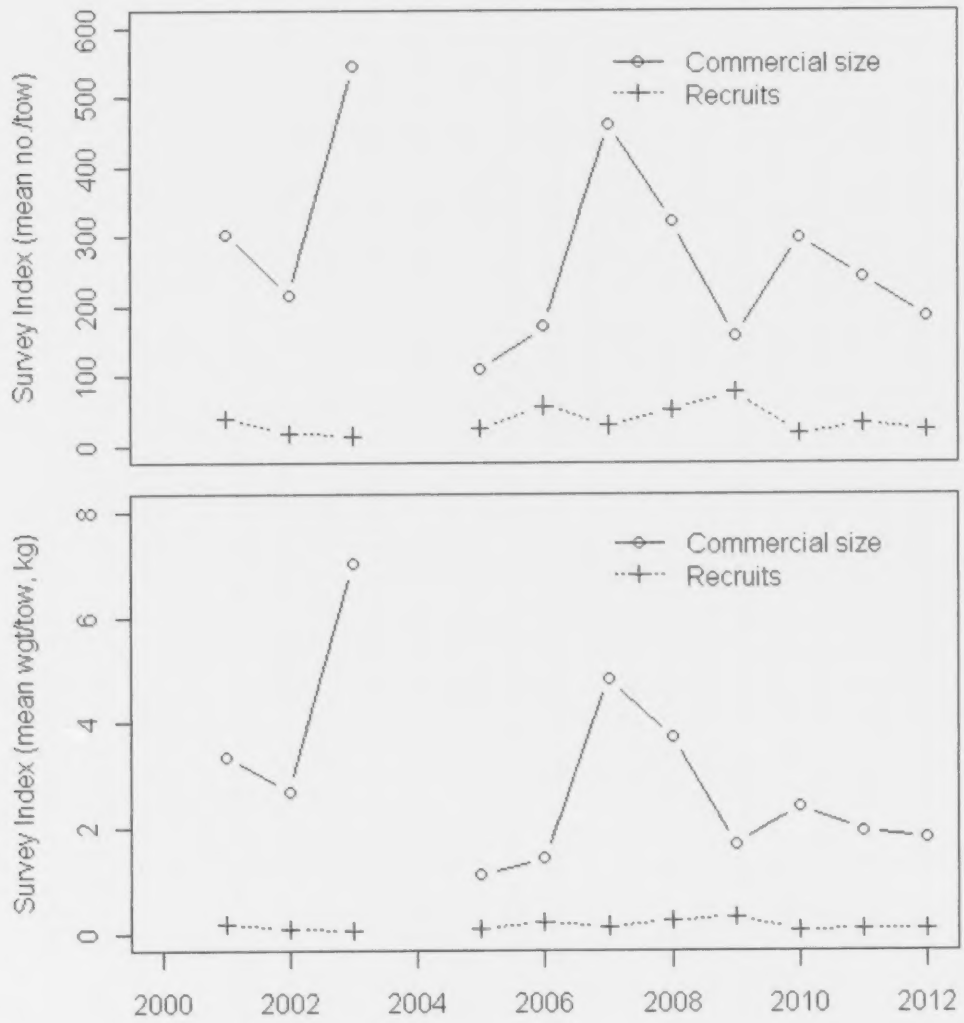

Figure 31. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for the Advocate zone of SPA 1B.

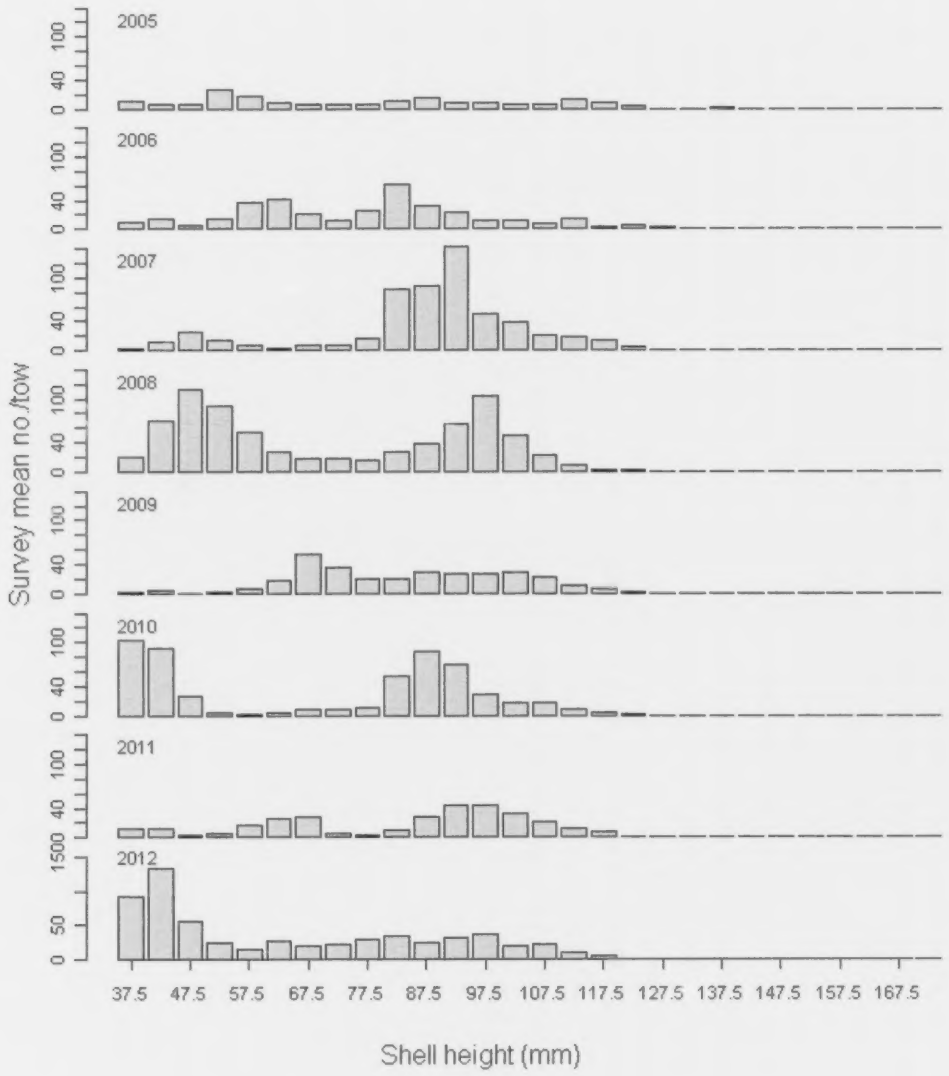

Figure 32. Scallop survey shell height frequencies (mean number/tow) for the Advocate zone of SPA 1B.

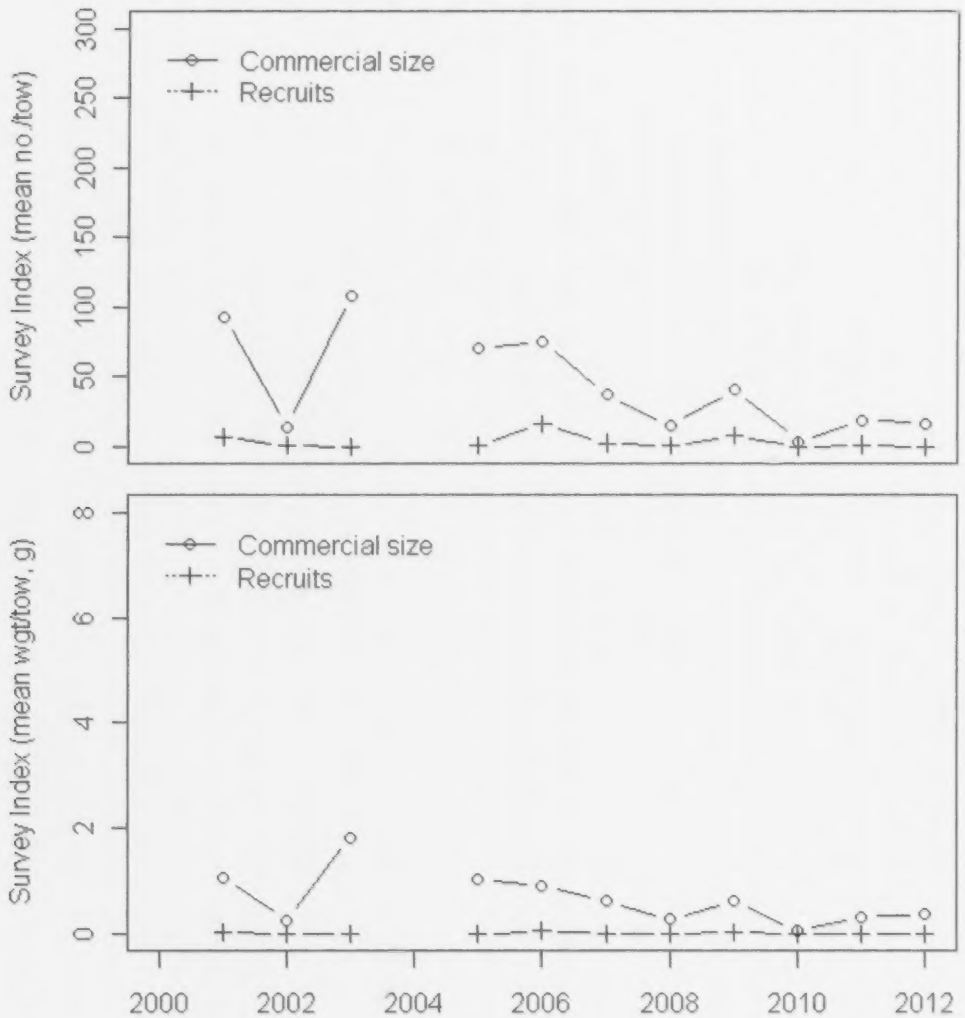

Figure 33. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for the Outer (28D) zone of SPA 1B.

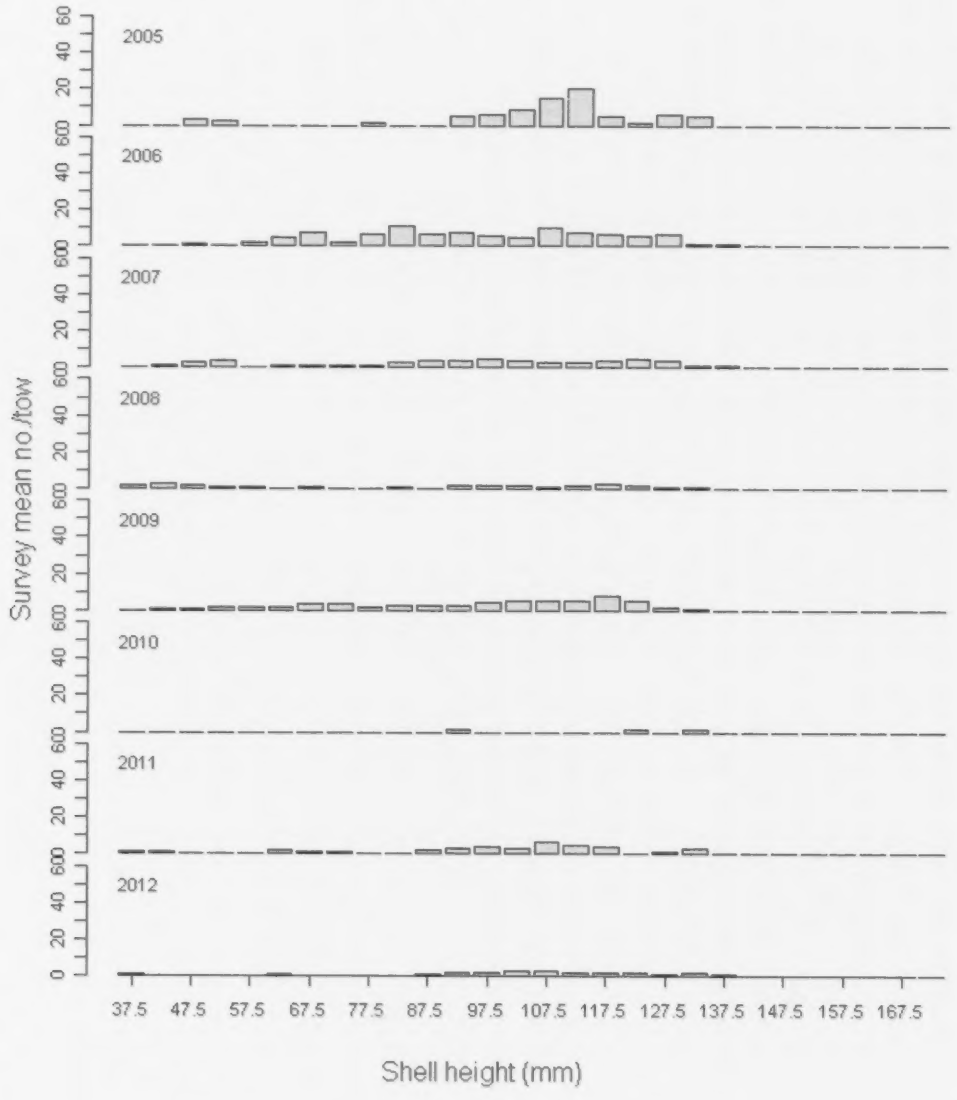

Figure 34. Scallop survey shell height frequencies (mean number/tow) for the Outer (28D) zone of SPA 1B.

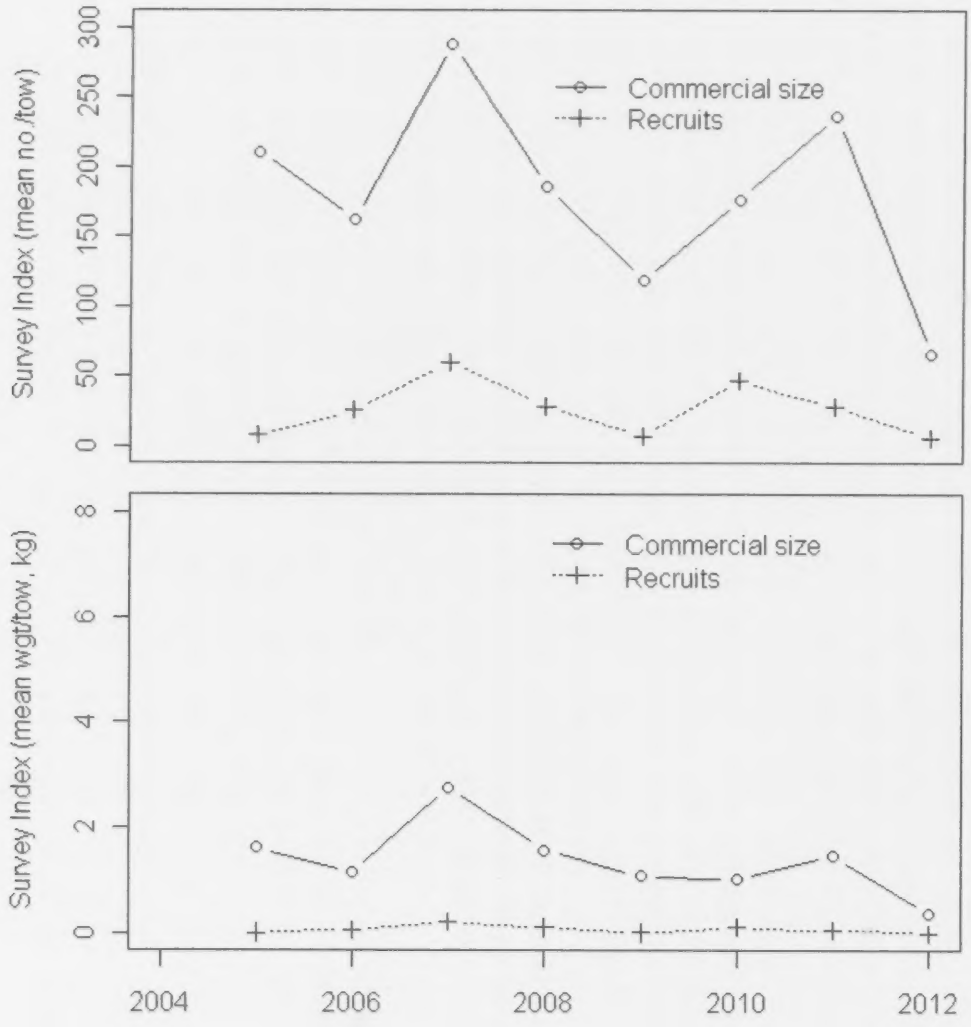

Figure 35. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for the Spencer's Island zone of SPA 1B.

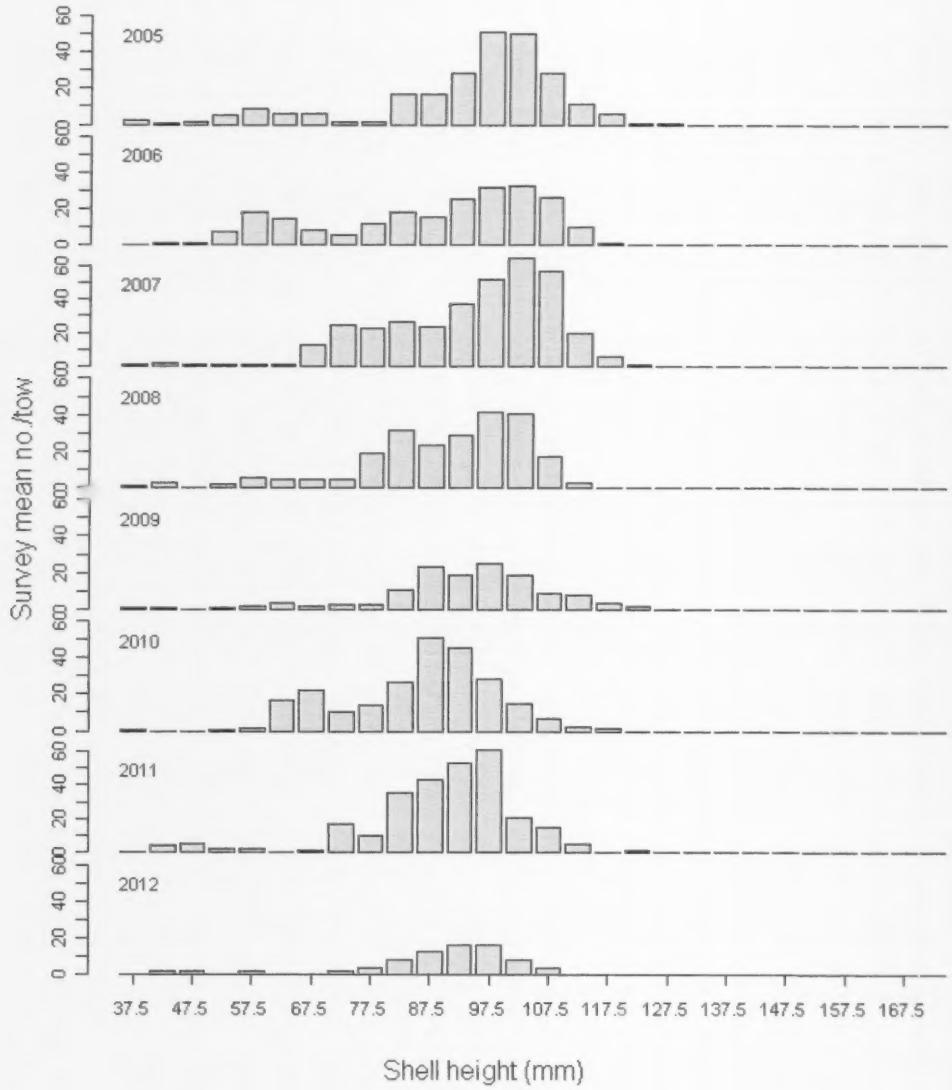

Figure 36. Scallop survey shell height frequencies (mean number/tow) for the Spencer's Island zone of SPA 1B.

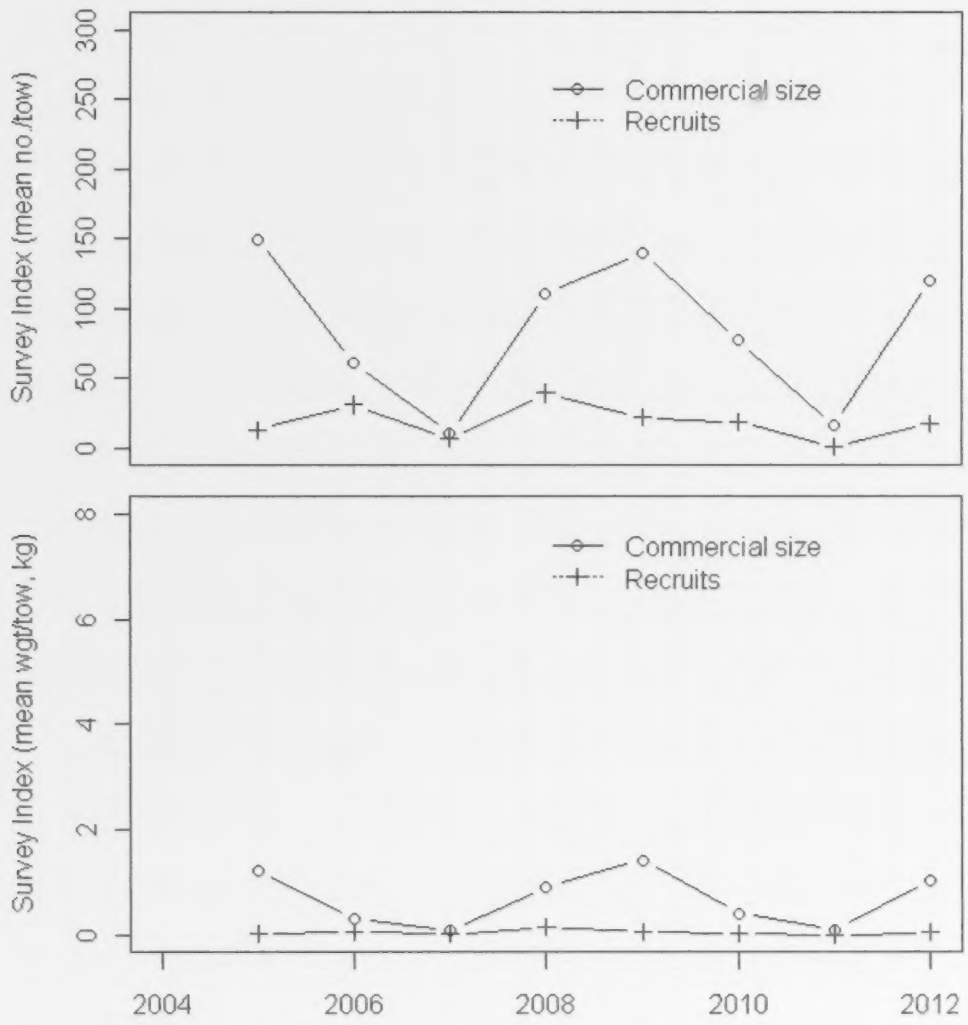

Figure 37. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for the Scots Bay zone of SPA 1B.

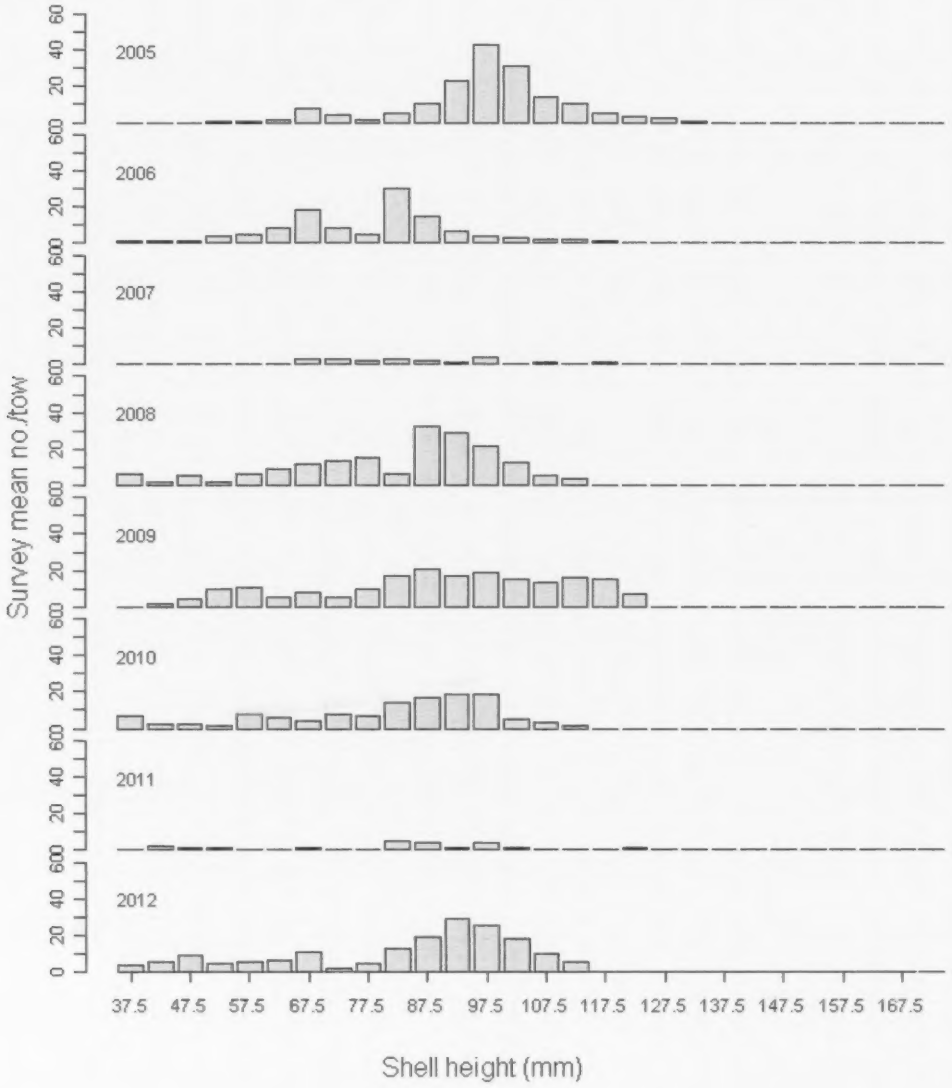

Figure 38. Scallop survey shell height frequencies (mean number/tow) for the Scots Bay zone of SPA 1B.

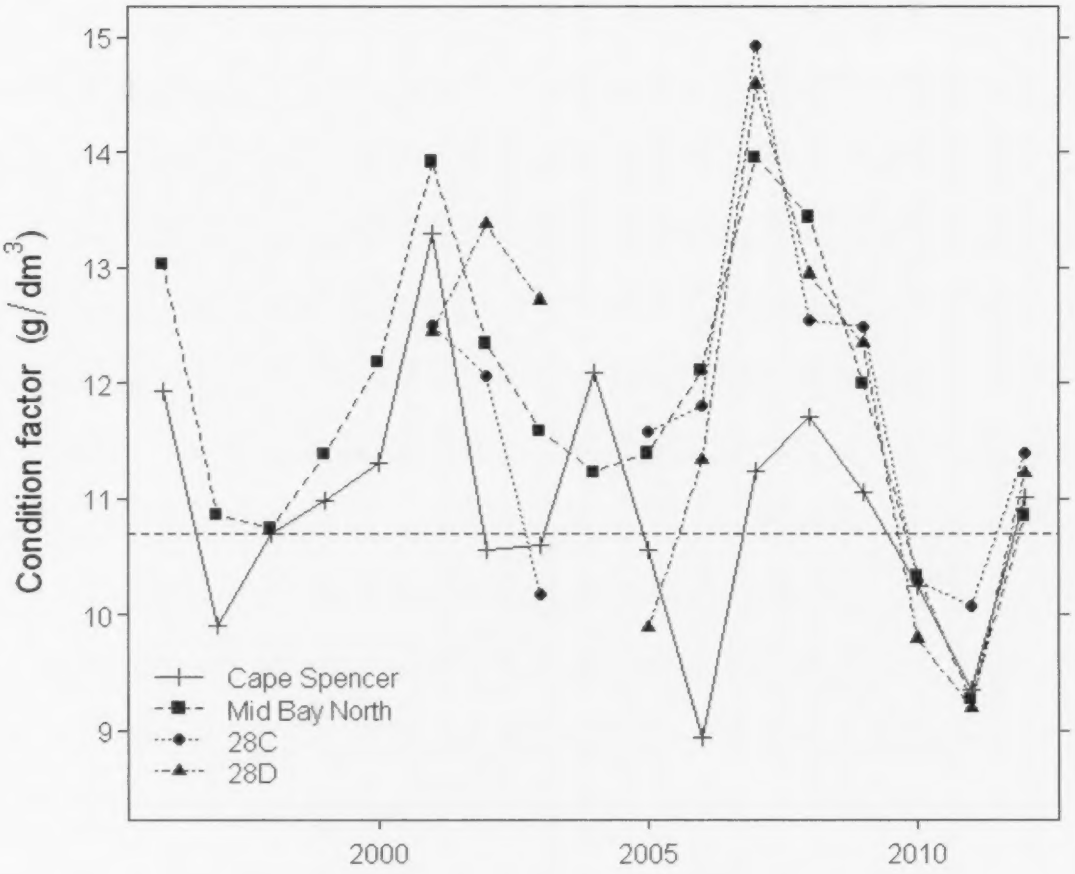

Figure 39. SPA 1B trend in condition factor (g/dm^3) from the annual survey.

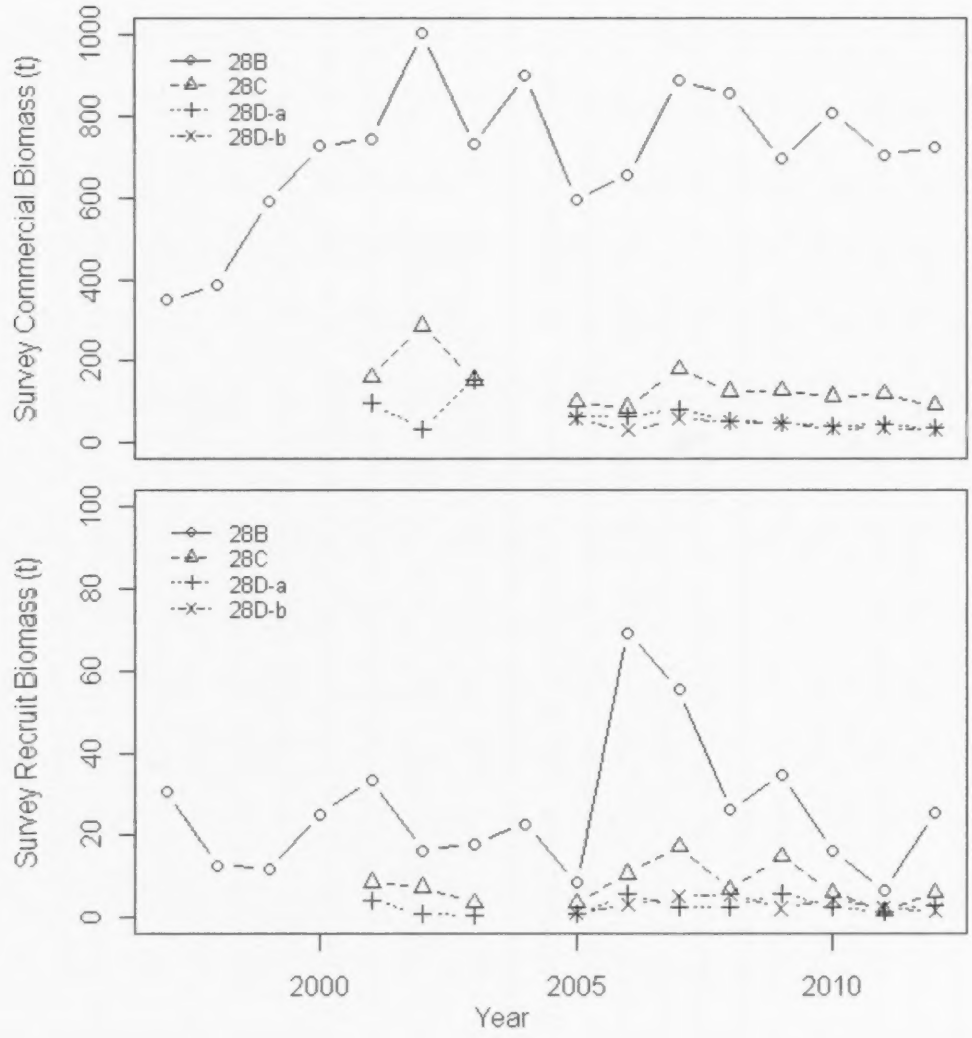

Figure 40. SPA 1B survey biomass (tons) for commercial (≥80 mm; upper) and recruit (65-79 mm; lower) in areas 28B (Cape Spencer and Middle Bay North), 28C, 28D-a (Advocate and Outer), and 28D-b (Spencer's Island and Scots Bay).

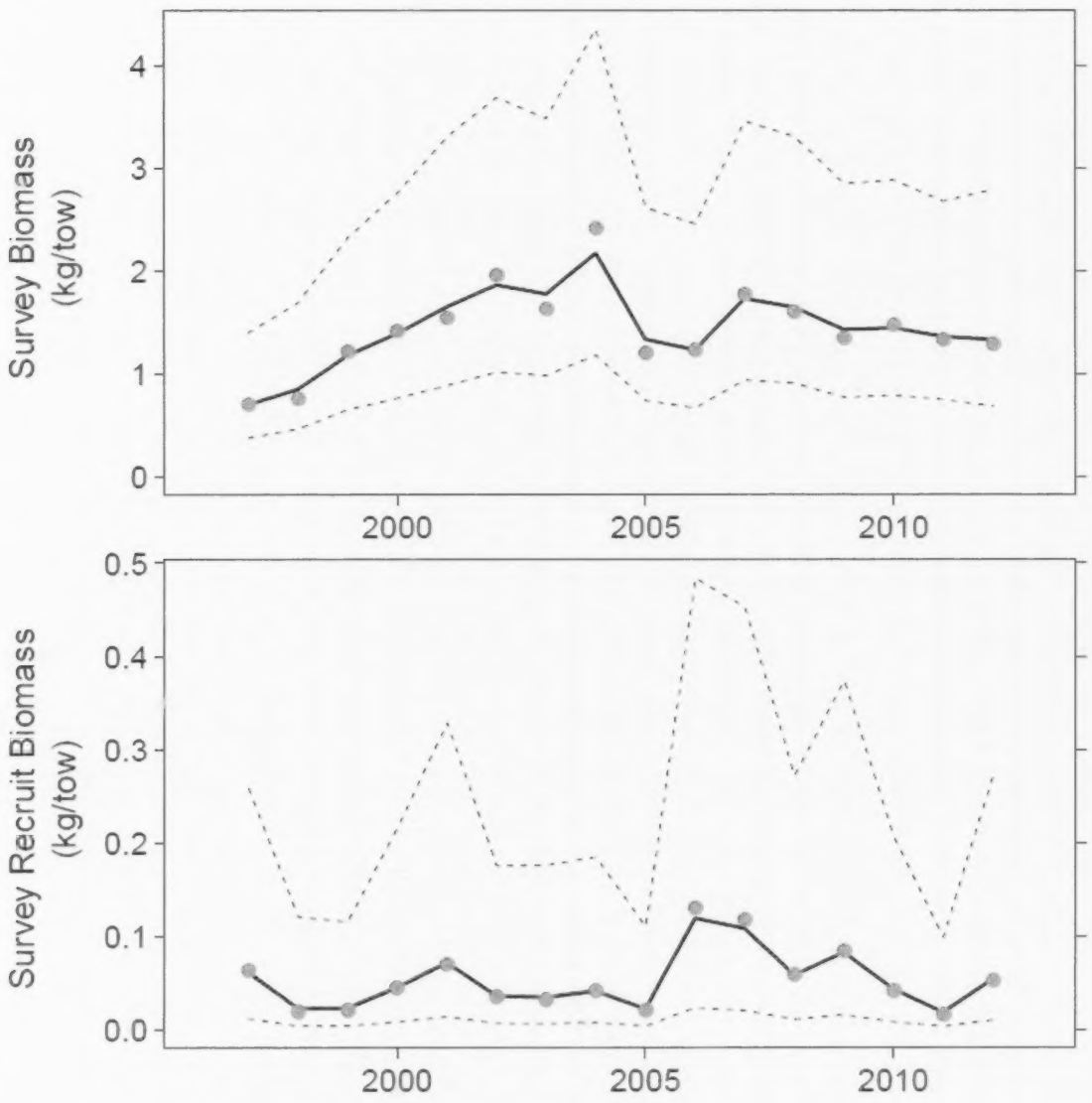

Figure 41. Posterior median fit to the survey series for commercial size and recruit size scallops. Bayesian state-space delay-difference model for scallops in SPA 1B.

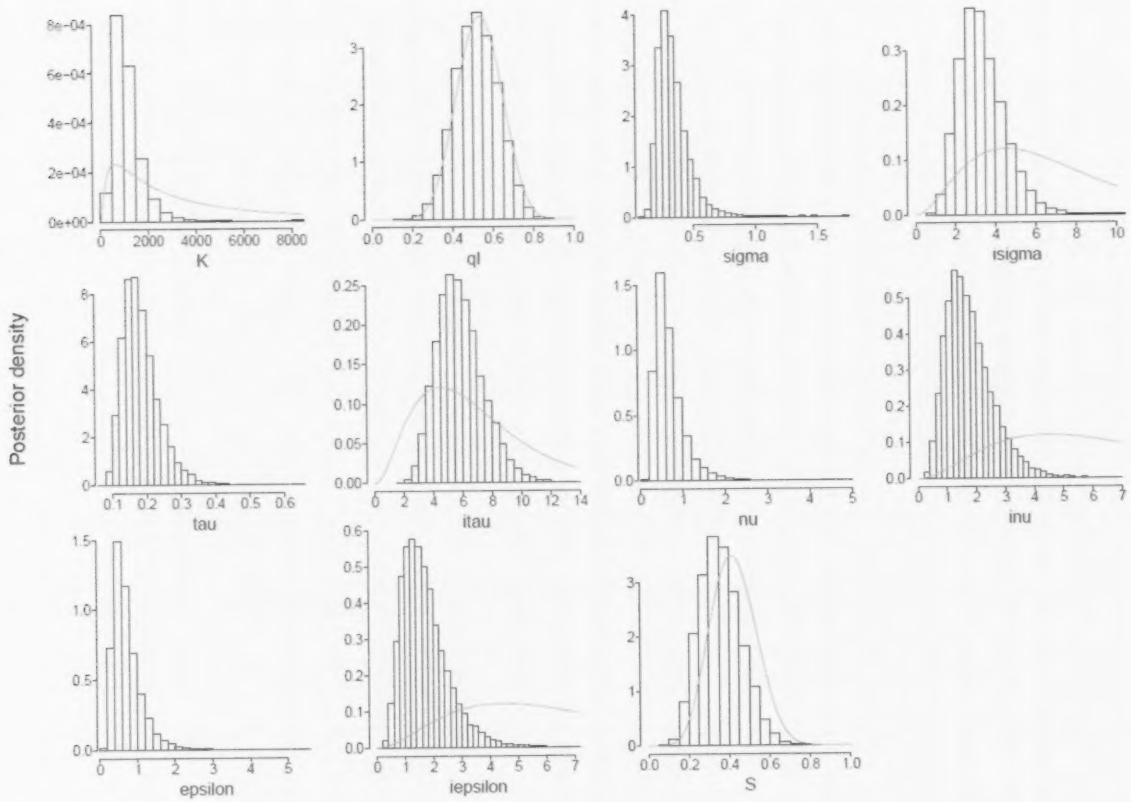

Figure 42. Comparison of prior and posterior densities. Bayesian state-space delay-difference model for scallops in SPA 1B.

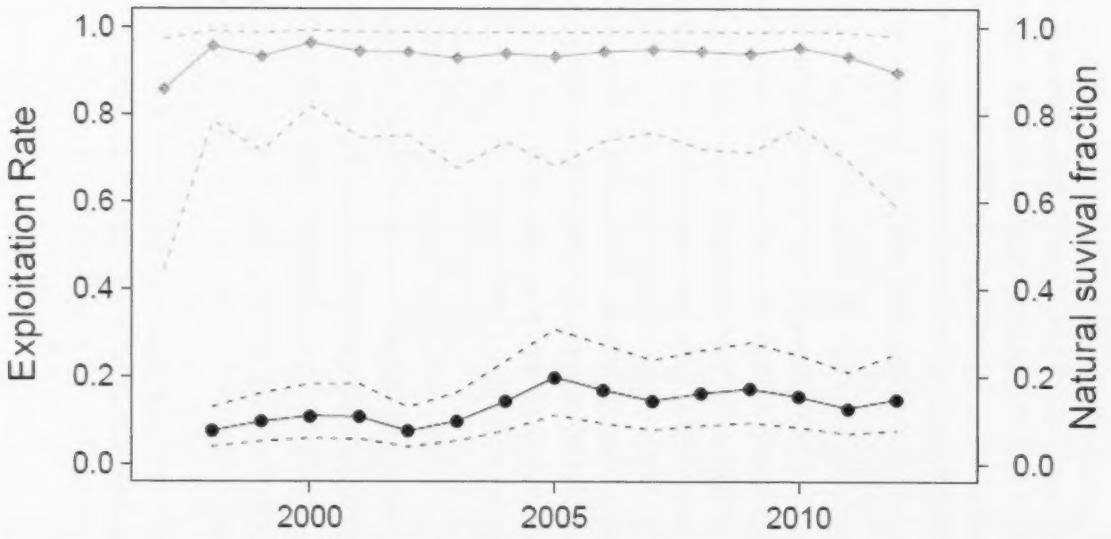

Figure 43. Annual trends in exploitation (black line, circles) and survival estimates ($exp(-m)$, where m is natural mortality; grey line, squares). Bayesian state-space delay-difference model for scallops in SPA 1B.

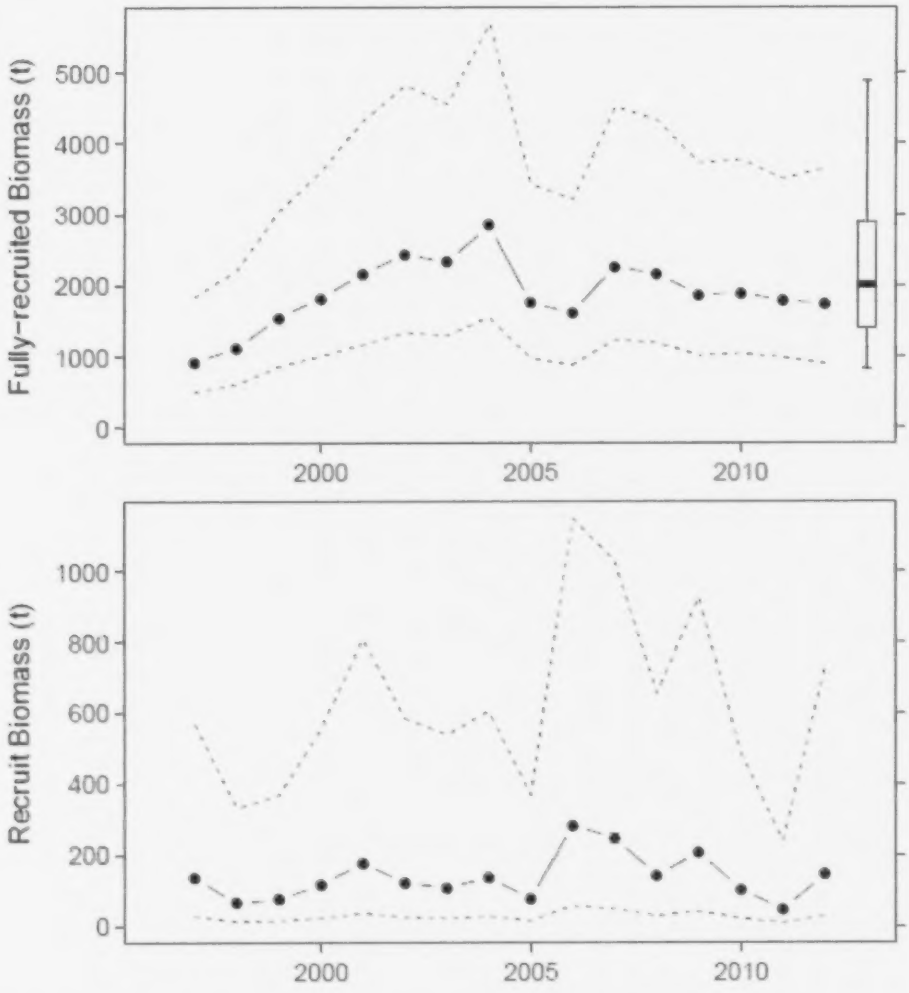

Figure 44. Biomass estimates for fully recruited scallops from the delay-difference model fit to the SPA 1B survey and commercial data. Dashed lines are the upper and lower 95% credible limits on the estimates. The predicted commercial size biomass for 2013, assuming the interim TAC (100 t), is displayed as a box plot with median, 50% credible limits (box) and 80% credible limits (whiskers).

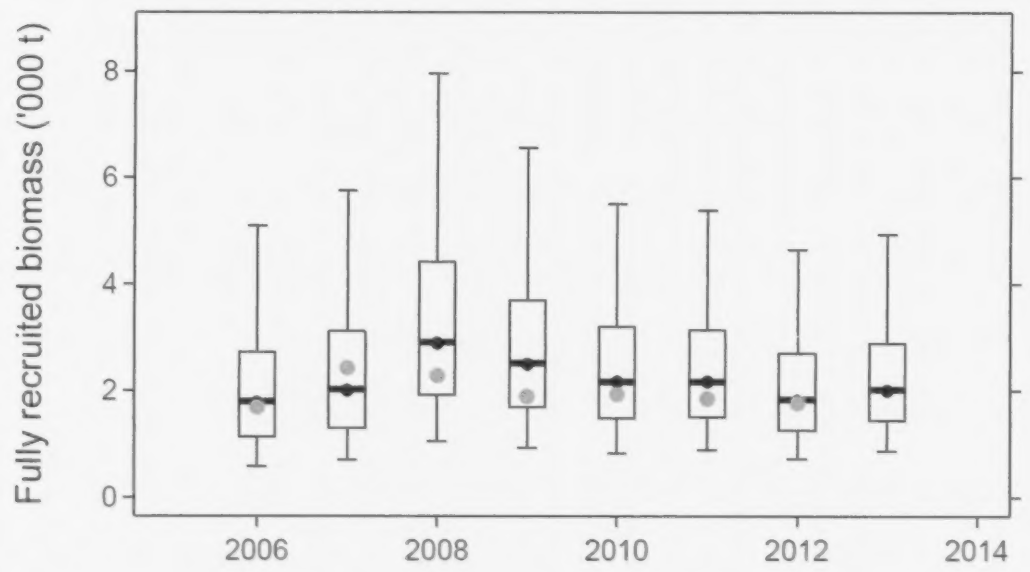

Figure 45. Evaluation of the model projection performance. Box and whisker plots summarize posterior distribution of commercial size biomass in year t based on model fit to year t-1 (e.g., 2006 prediction based on data up to 2005). Red dot represents the estimate of the biomass in year t using data up to and including year t. Bayesian state-space delay-difference model for scallops in SPA 1B.

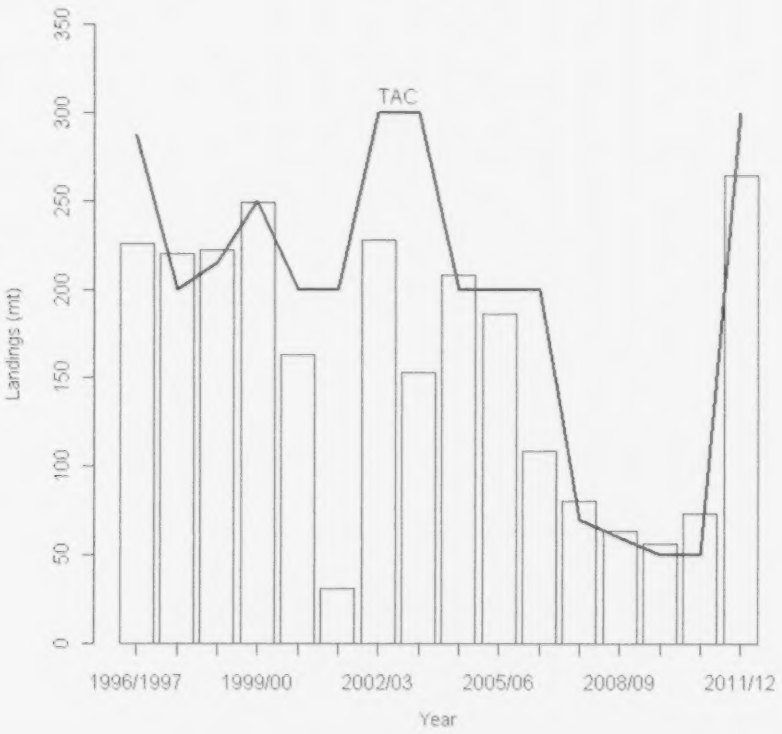

Figure 46. SPA 3 landings (meat, tons) by the Full Bay fleet.

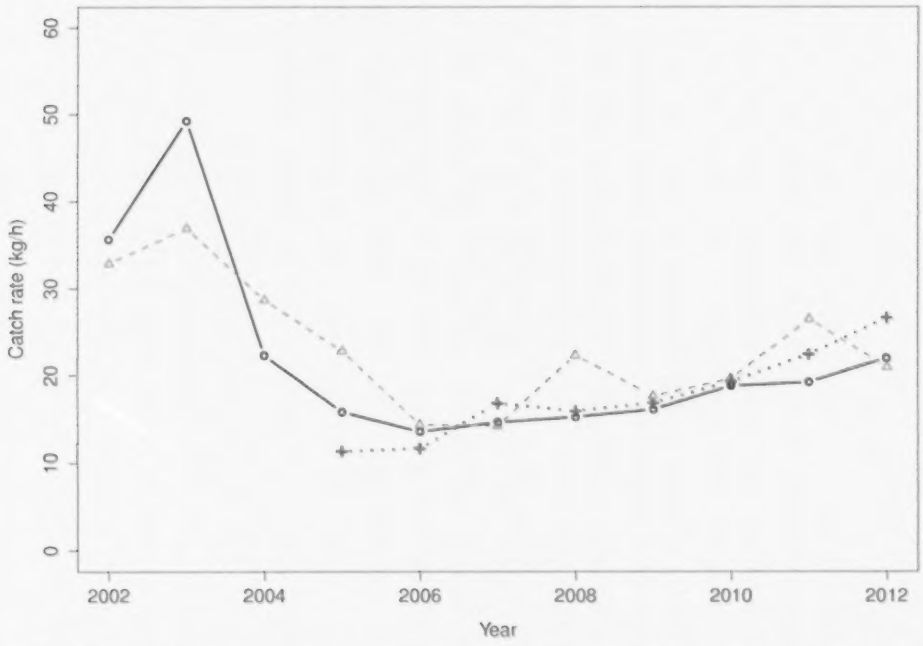

Figure 47. Commercial catch rates (kg/h) in SPA 3 by the Full Bay Fleet. Catch rates given as Brier/Lurcher for summer fishery (black line, circles), St. Mary's Bay (red dashed line, triangles) and October fishery in Brier/Lurcher (blue dotted line, crosses).

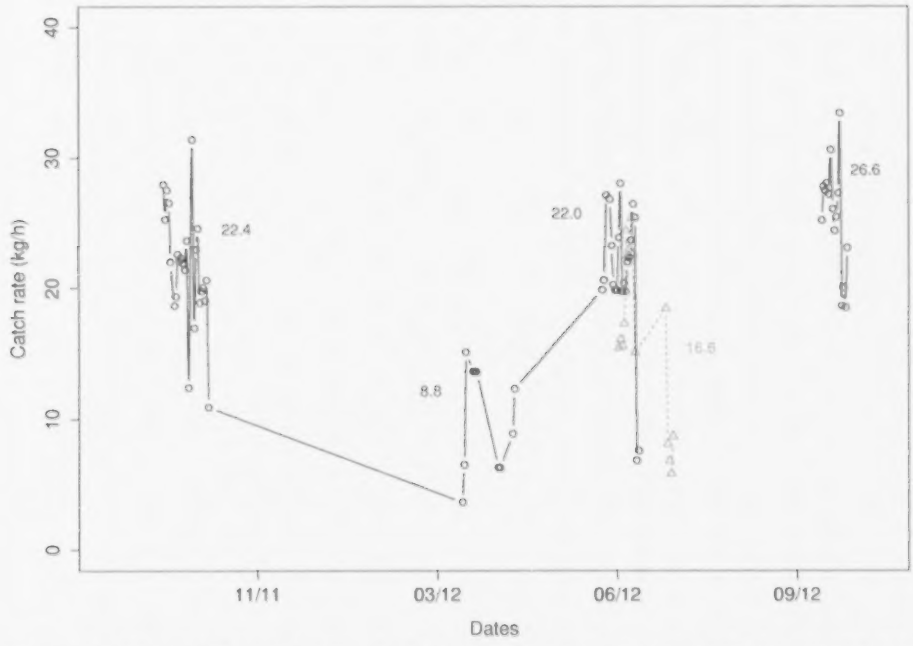

Figure 48. Mean daily catch rates (kg/h) from 1 October 2011 to 15 October 2012 in SPA 3 (excluding St. Mary's Bay) by the Full Bay Fleet. Catch rates in March/April correspond to fishing in subarea 3B only (see text). Catch rates in June/July are broken out by 3A (solid black line, open circle) and 3B (dashed red line with open triangles).

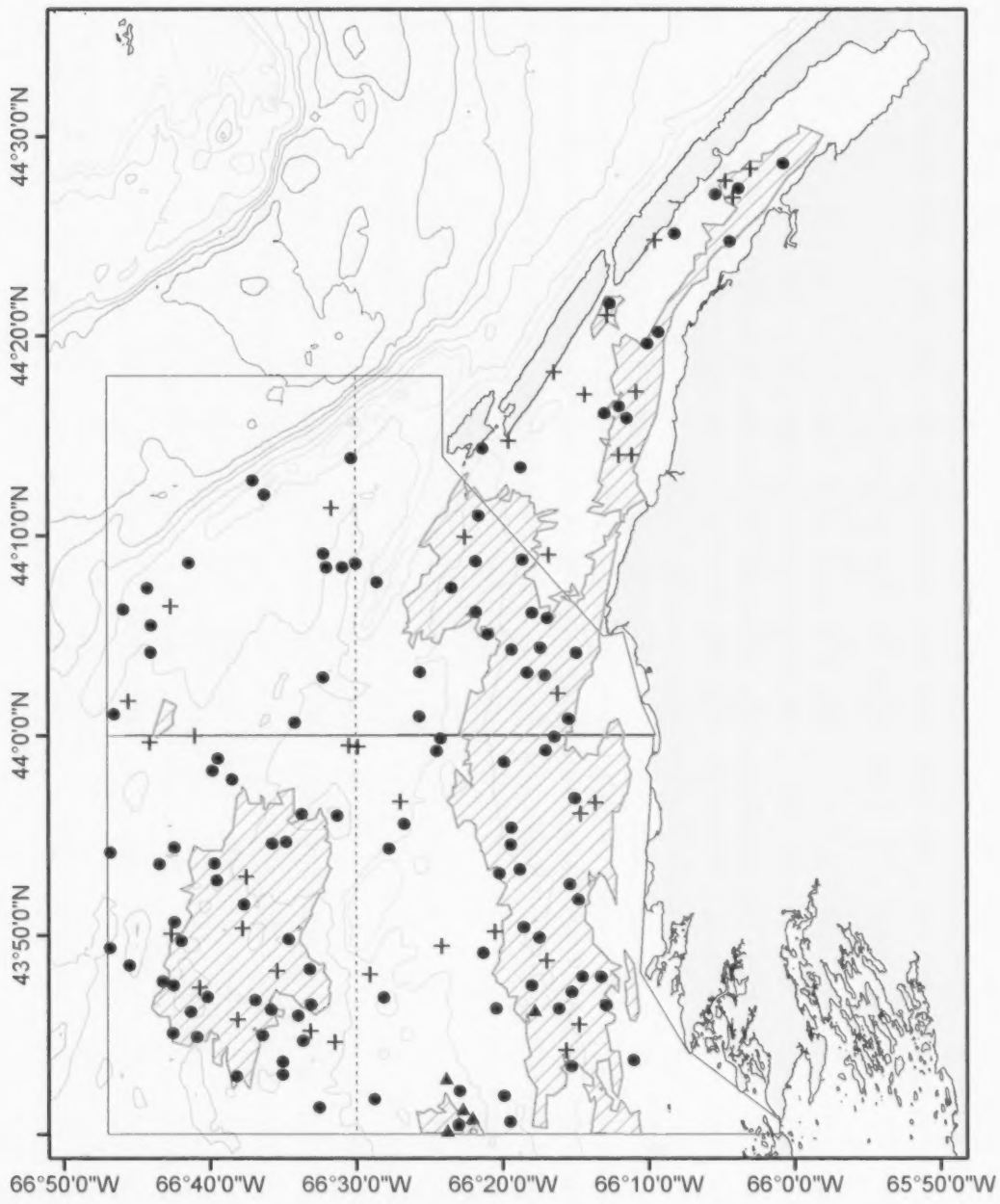

Figure 49. Polygon boundaries (red) are from the mean VMS "fishing" intensity from 2002 to 2010 for SPA 3, with a threshold of above 2 km per km^2. Survey positions for 2012 are indicated. Circles represent random stations, crosses represent positions from the 2011 survey that were sampled again in 2012 (repeated tows) and triangles indicate exploratory stations. The division between SPA 3A and 3B is indicated by the dashed black line.

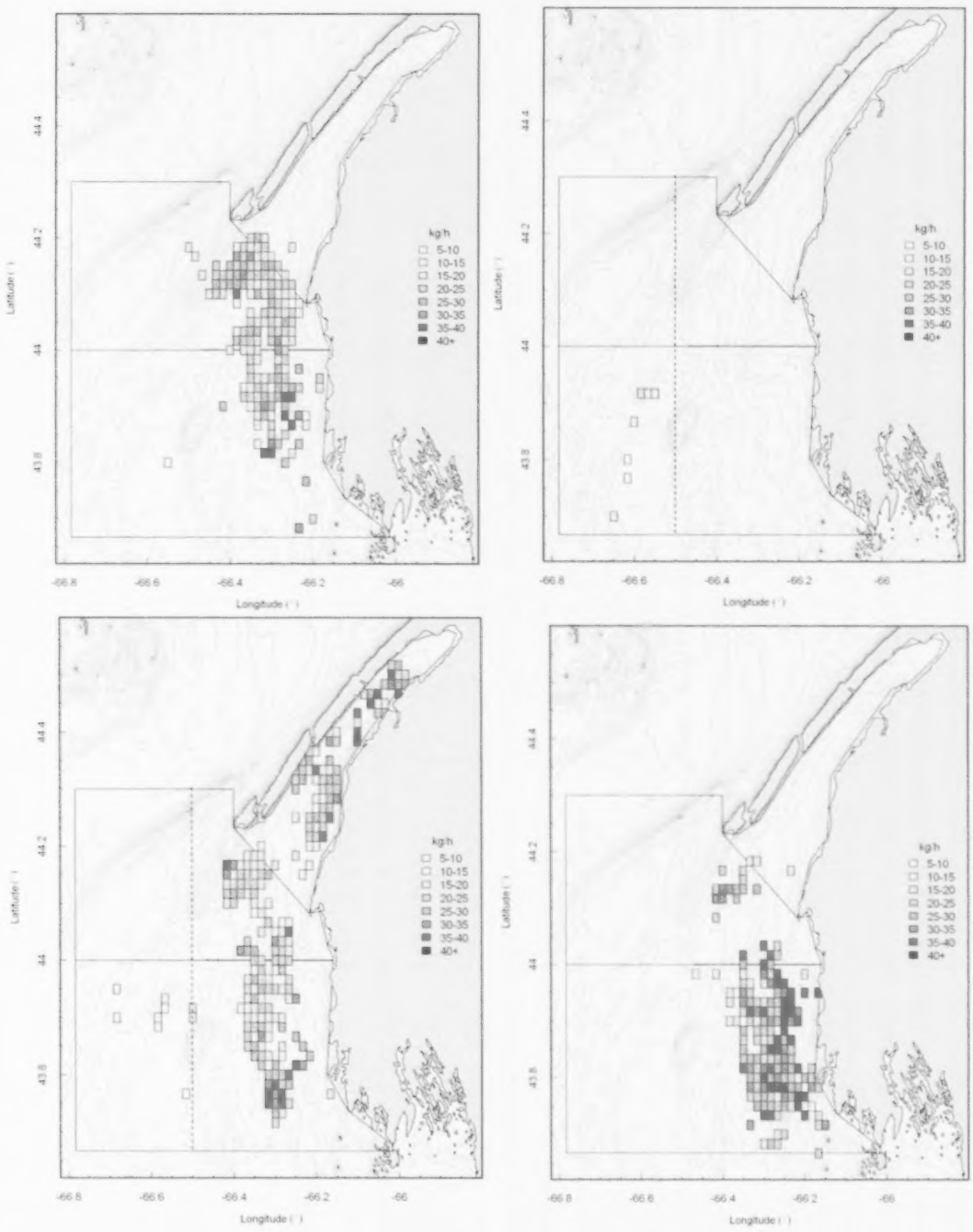

Figure 50. Mean catch rates by one minute square from commercial fishing logs for SPA 3 by the Full Bay Fleet. The division between 3A and 3B is indicated by the dashed black line. Top left: October 2011; top right: March and April 2012; bottom left: June and July 2012 (3A only fished in June, 3B open in July); bottom right: October 2012.

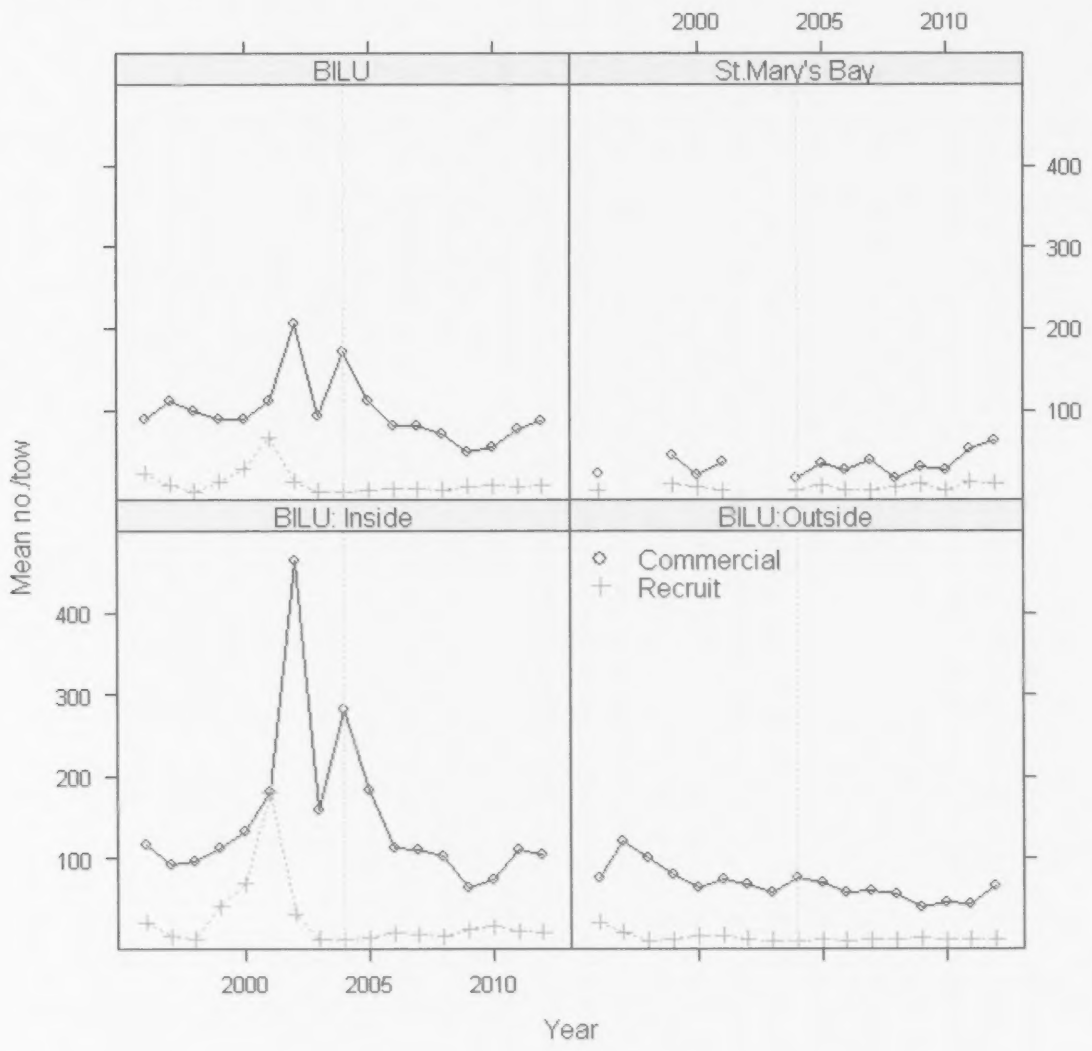

Figure 51. SPA 3 survey trends (mean number/tow) for commercial (≥80 mm) and recruit (65-79 mm) scallops. BILU = Brier/Lurcher area; BILU: Inside = area within red polygons in the Brier/Lurcher area shown in Figure 50; BILU: Outside = area outside red polygons in the Brier/Lurcher area shown in Figure 49. Vertical dotted line indicates a change in survey timing: previous to 2004 surveys were conducted in August and have been in June 2004 to present.

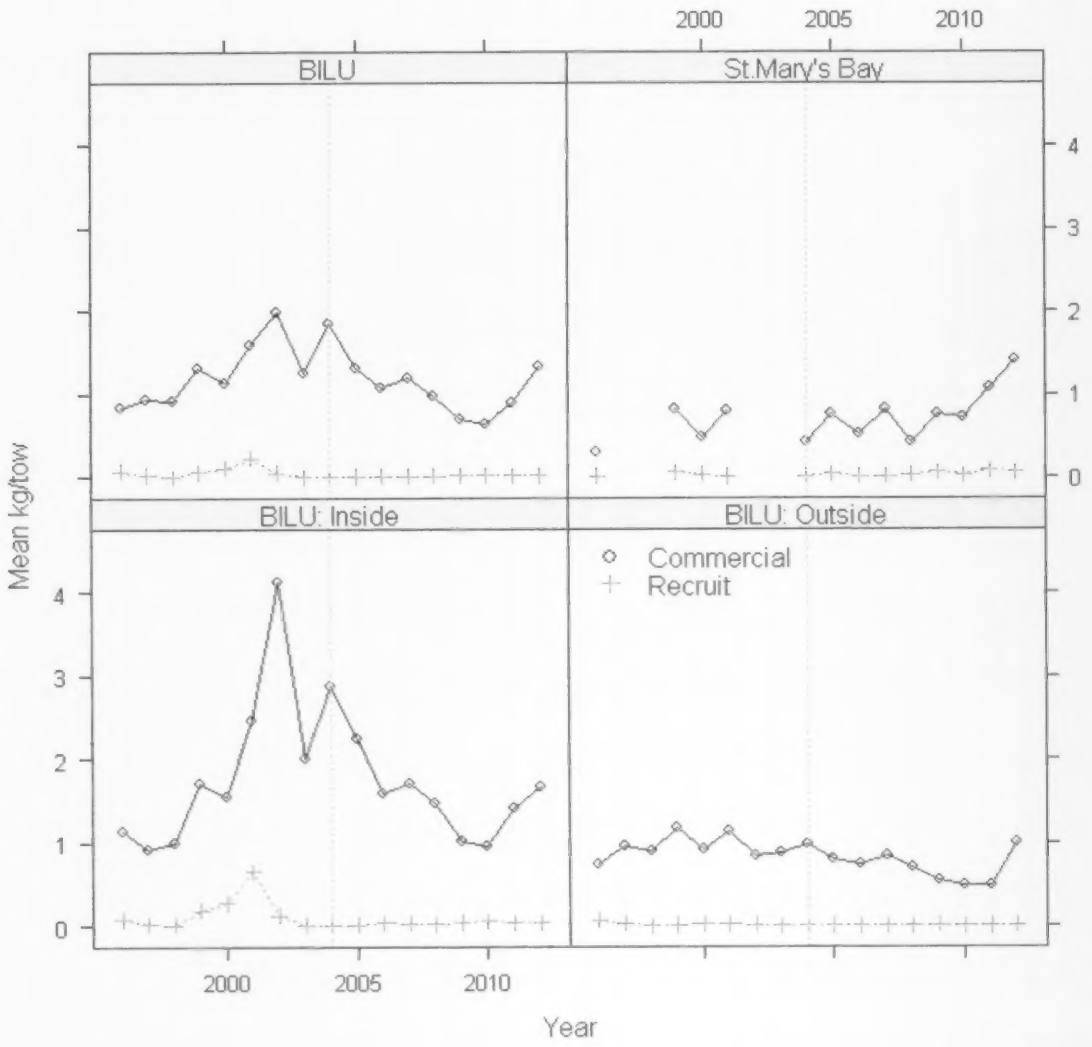

Figure 52. SPA 3 survey trends (mean weight/tow (kg)) for commercial (≥80 mm) and recruit (65-79 mm) scallops. BILU = Brier/Lurcher area; BILU: Inside = area within red polygons in the Brier/Lurcher area shown in Figure 49; BILU: Outside = area outside red polygons in the Brier/Lurcher area shown in Figure 49. Vertical dotted line indicates a change in survey timing: previous to 2004 surveys were conducted in August and have been in June 2004 to present.

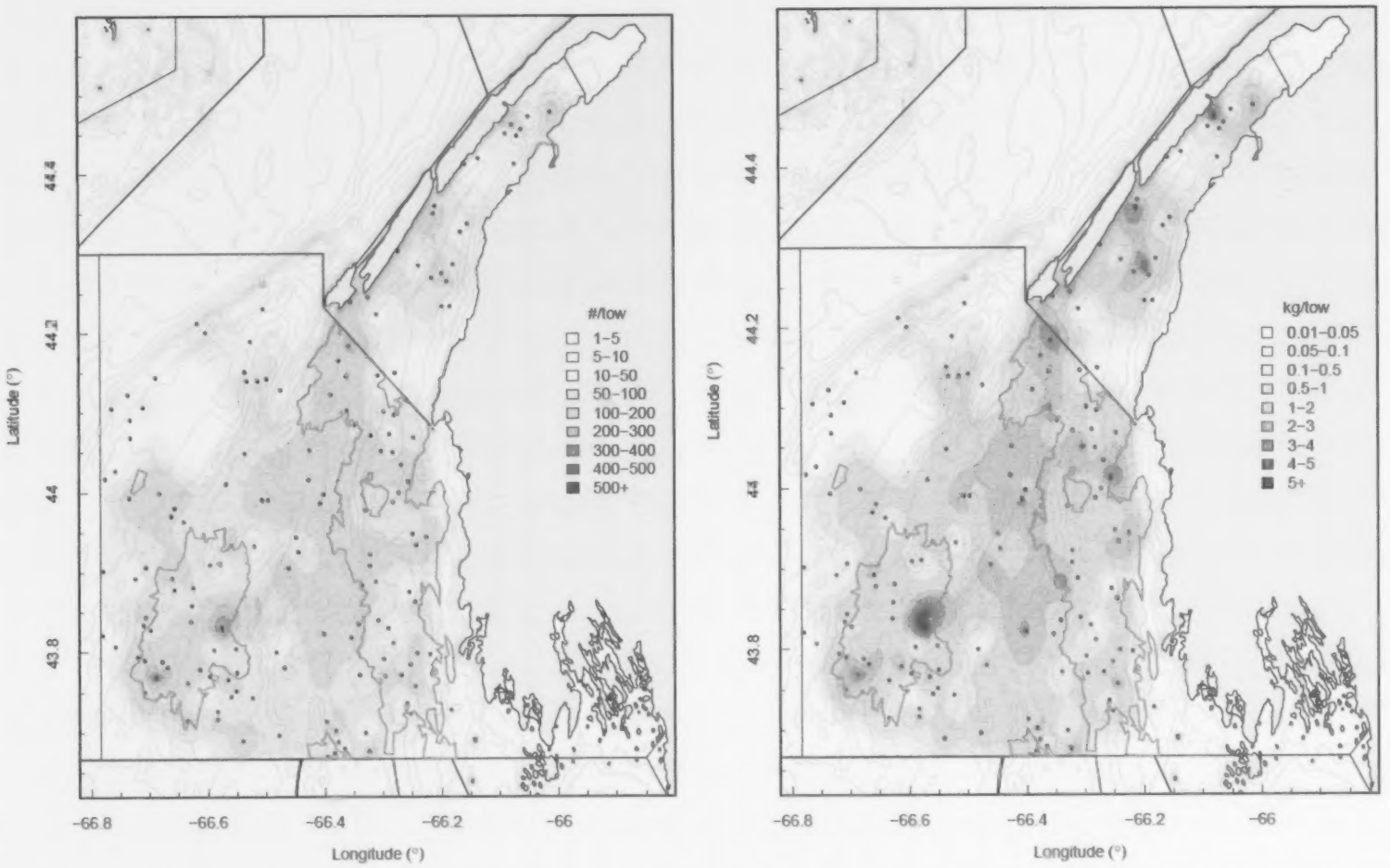

Figure 53. Spatial density of number/tow (left) and kg/tow (right) of commercial scallop (≥80 mm) from the 2012 survey for SPA 3. Red polygons indicate the Inside and Outside strata (see Figure 49).

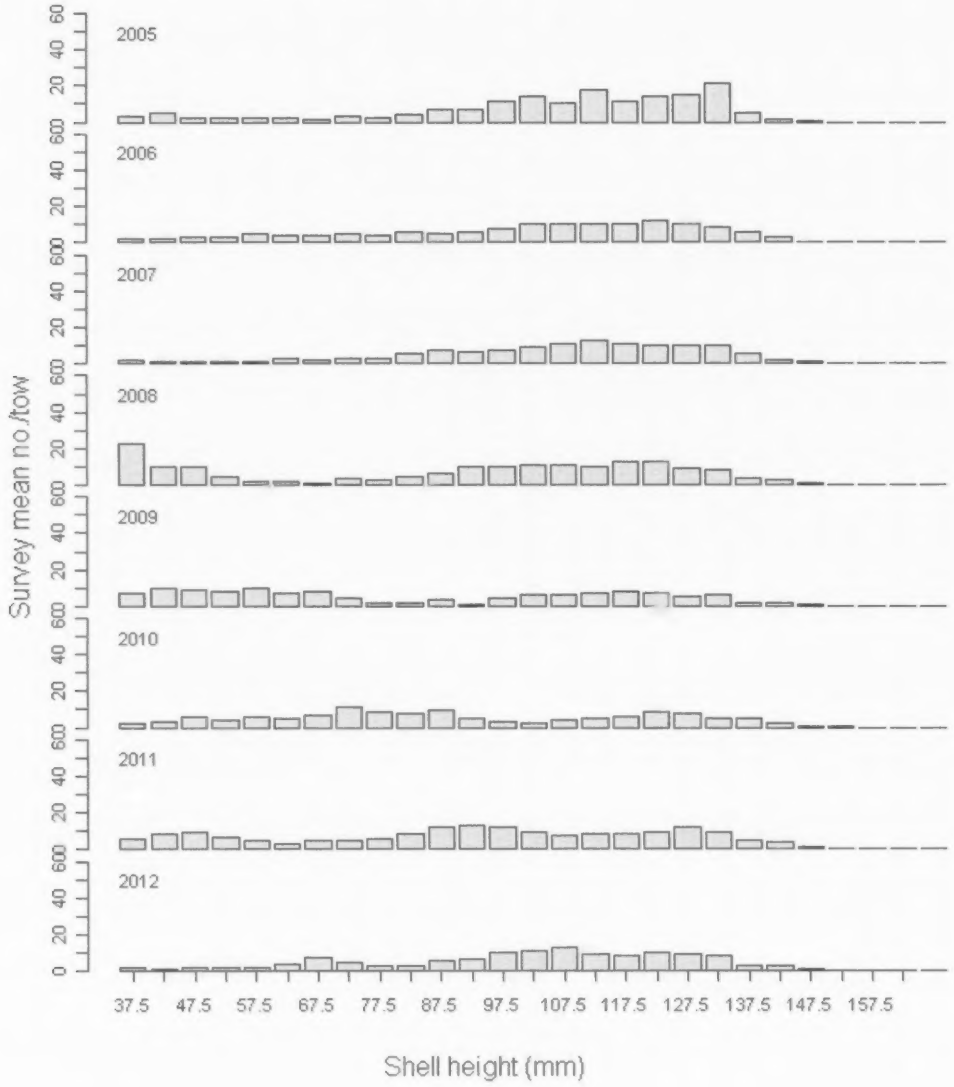

Figure 54. Scallop survey shell height frequencies (mean number/tow) for the St. Mary's Bay zone of SPA 3.

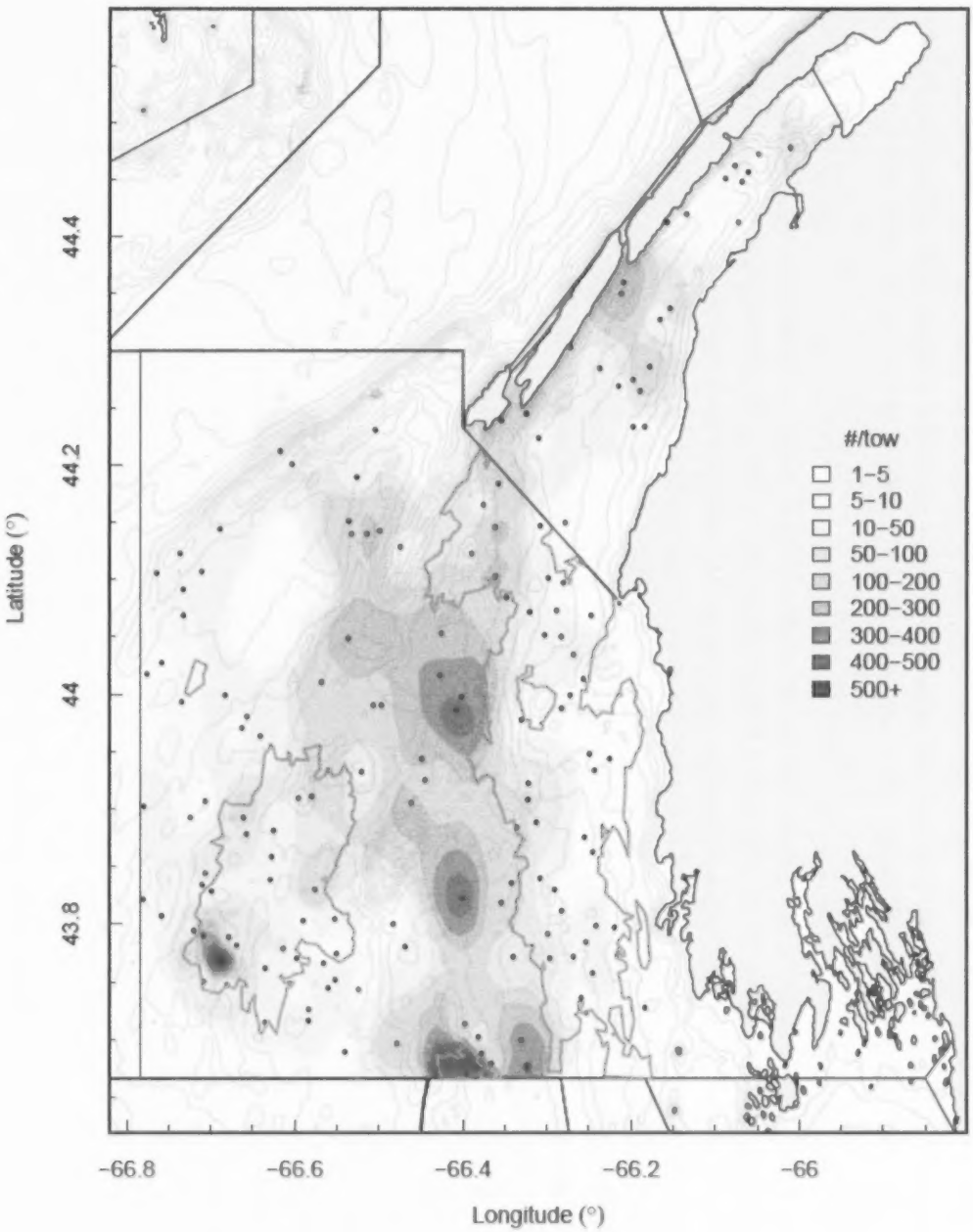

Figure 55. Spatial density (number/tow) of pre-recruit scallop (<65 mm) from the 2012 survey for SPA 3. Red polygons indicate the Inside and Outside strata (see Figure 49).

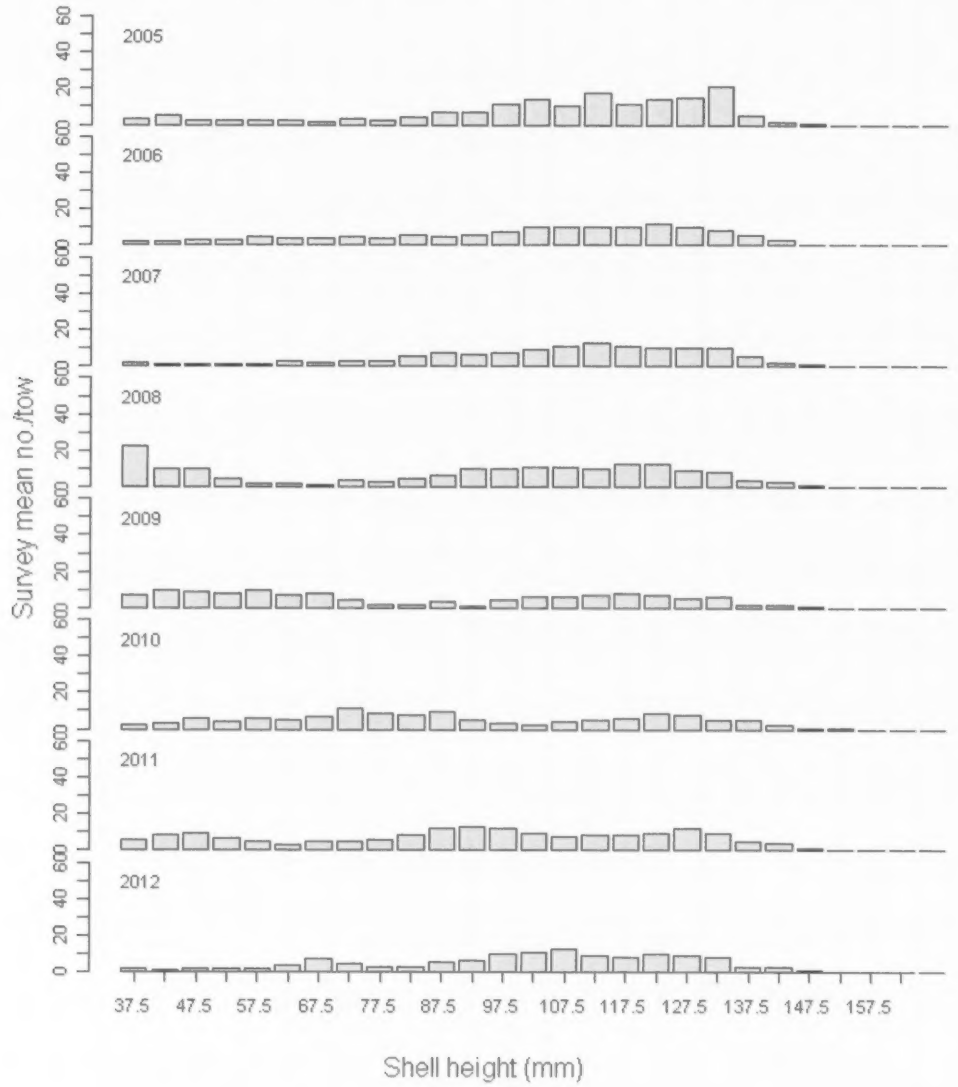

Figure 56. Scallop survey shell height frequencies (mean number/tow) for the Brier/Lurcher Inside (Figure 49) zone of SPA 3.

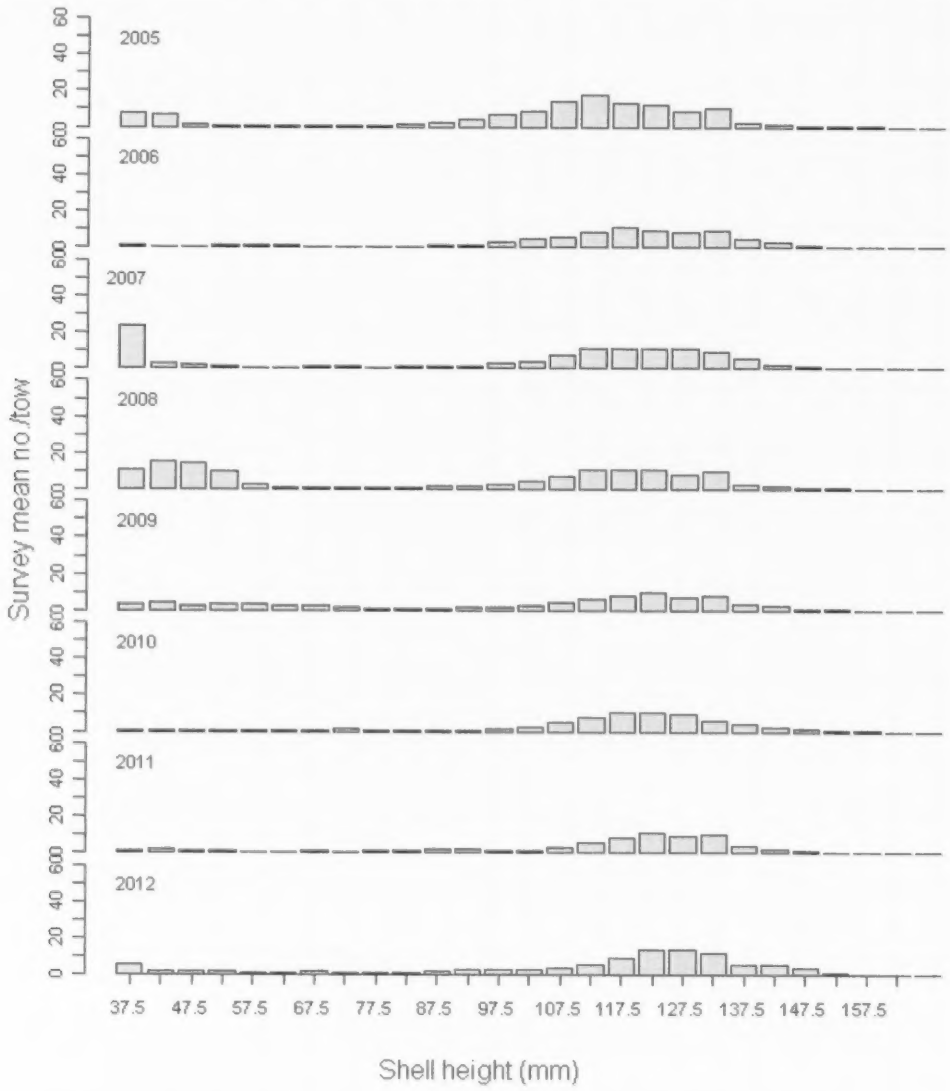

Figure 57. Scallop survey shell height frequencies (mean number/tow) for the Brier/Lurcher Outside (Figure 49) zone of SPA 3.

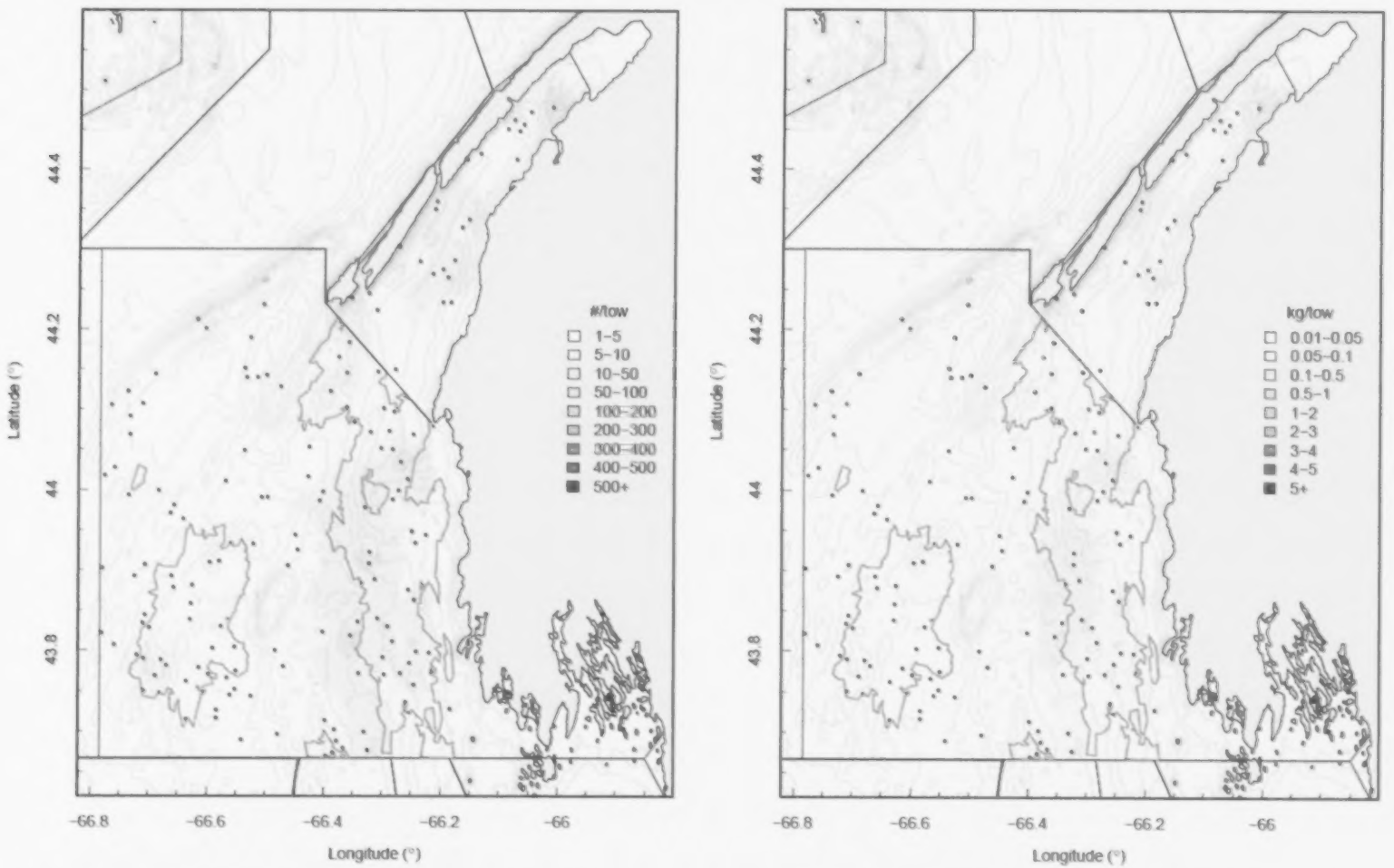

Figure 58. Spatial density of number/tow (left) and kg/tow (right) of recruit scallop (65-79 mm) from the 2012 survey for SPA 3. Red polygons indicate the Inside and Outside strata (see Figure 49).

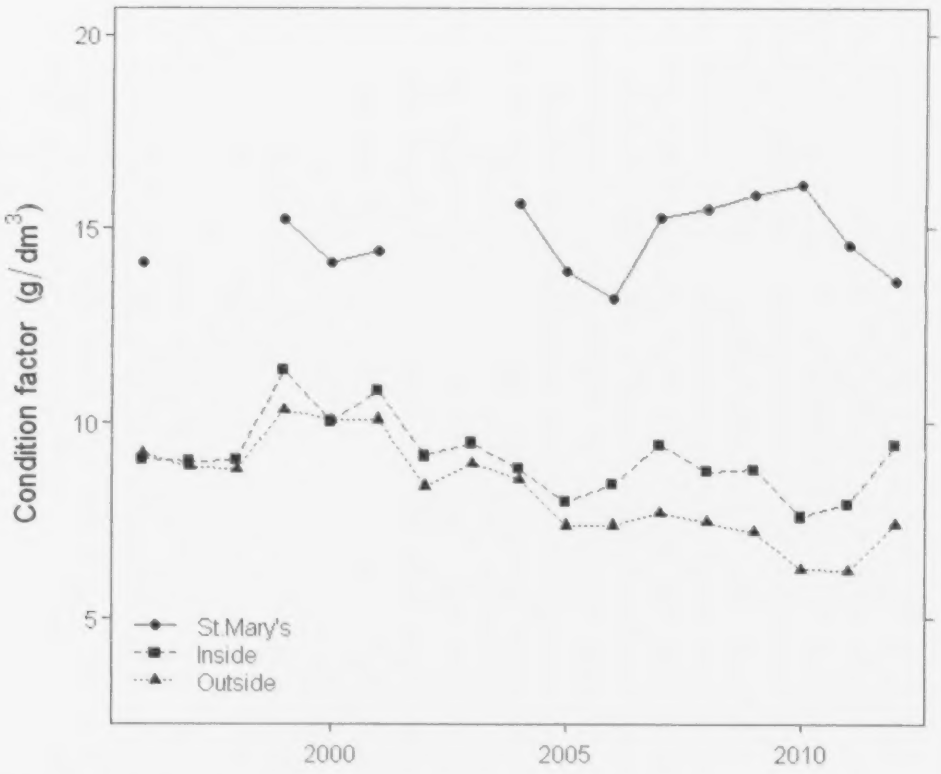

Figure 59. SPA 3 trend in condition factor (g/dm^3) from the annual survey.

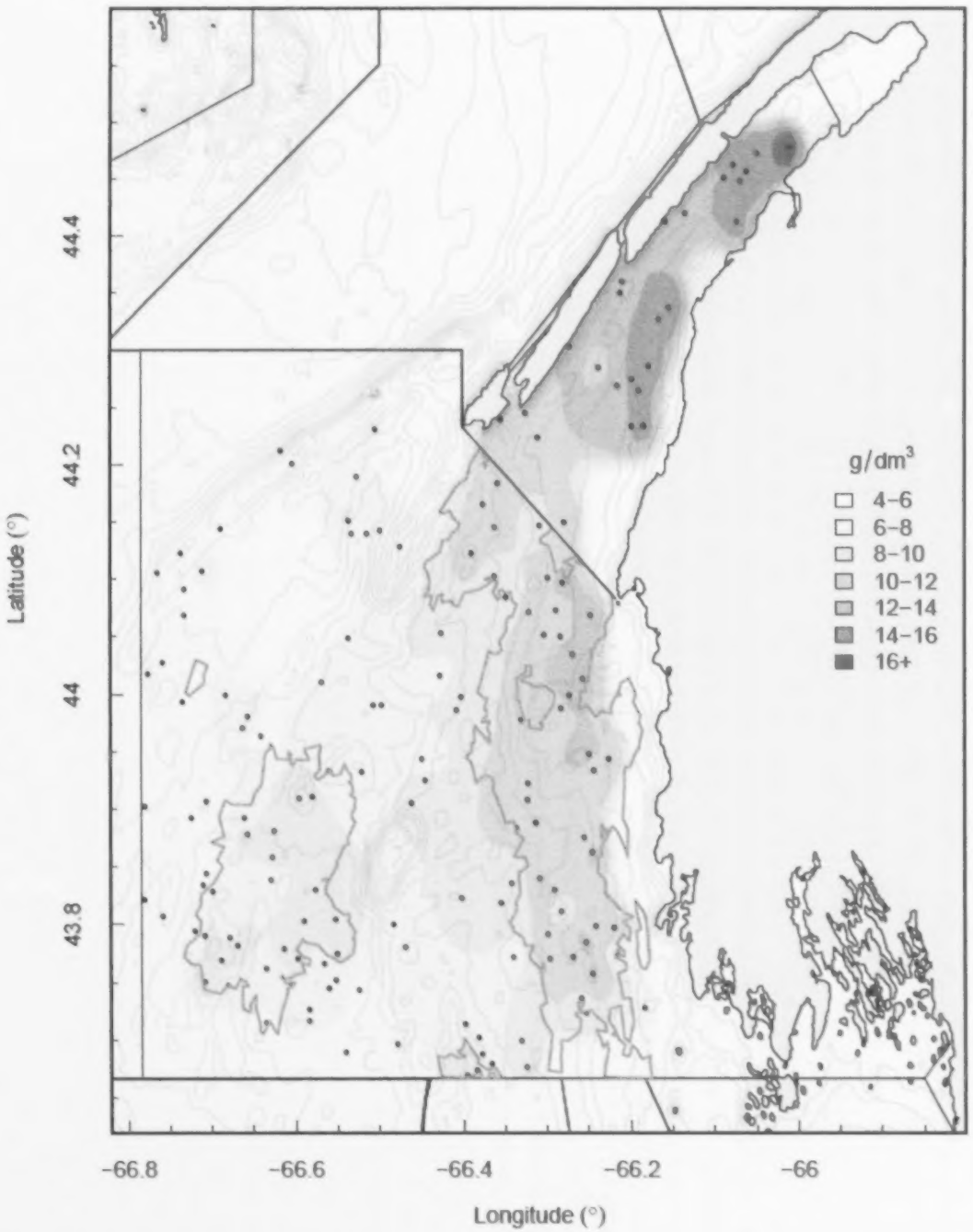

Figure 60. Spatial distribution of condition factor (g/dm^3) from the 2012 survey for SPA 3. Red polygons indicate the Inside and Outside strata (see Figure 49).

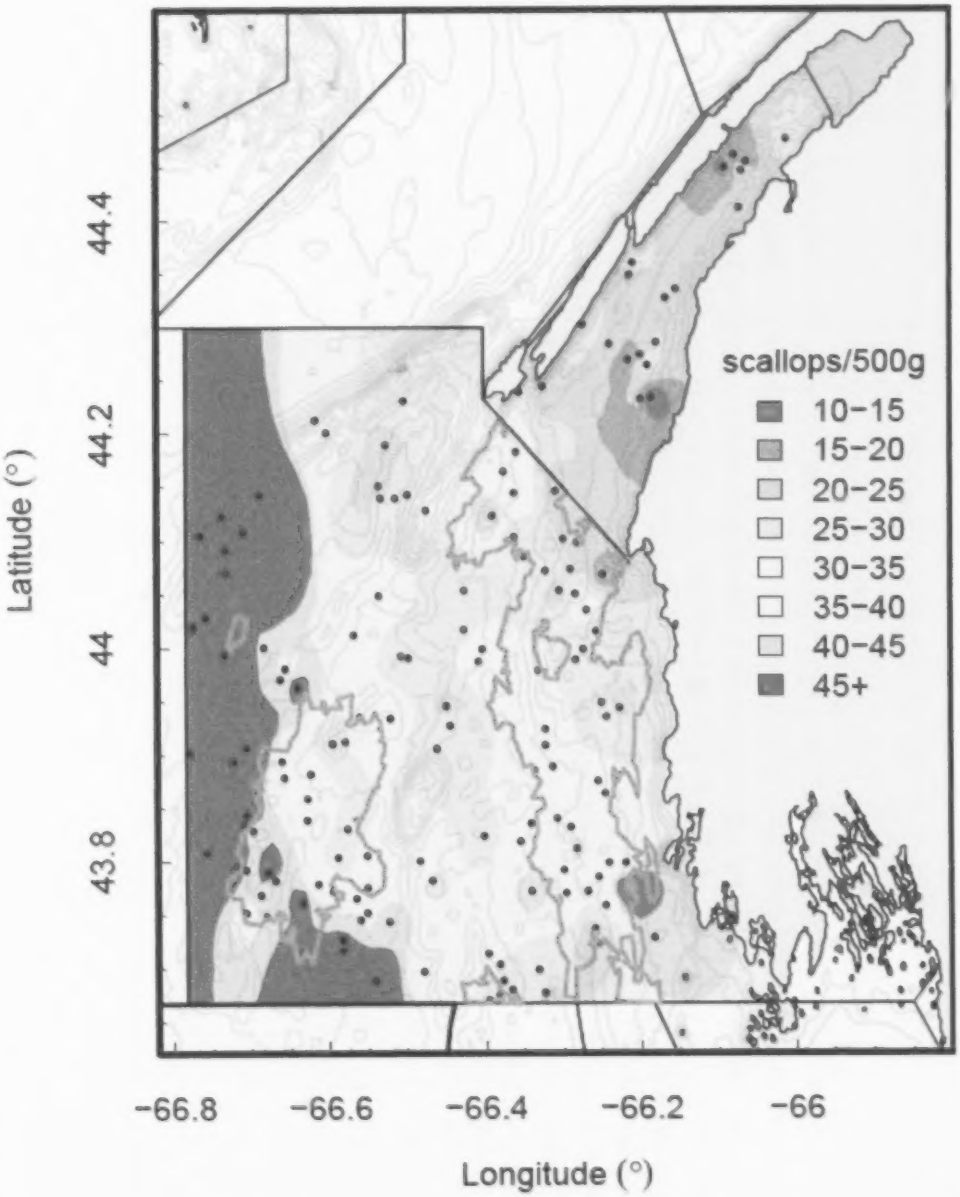

Figure 61. Spatial distribution of meat count (scallops/500g) from the 2012 survey for SPA 3. Red polygons indicate the Inside and Outside strata (see Figure 49).

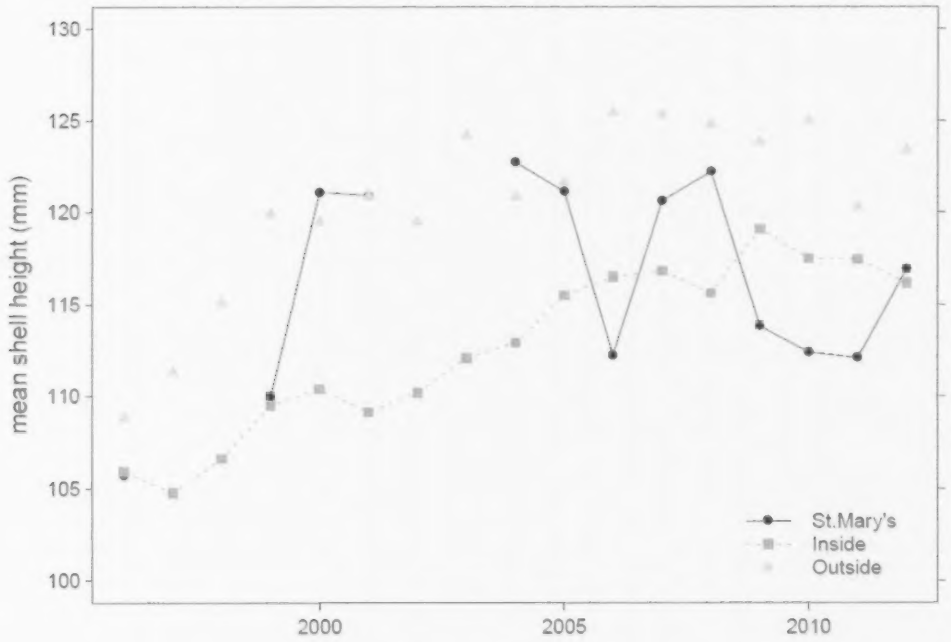

Figure 62. SPA 3 trend in mean shell height (mm) of commercial scallops (> 80mm) from the annual survey.

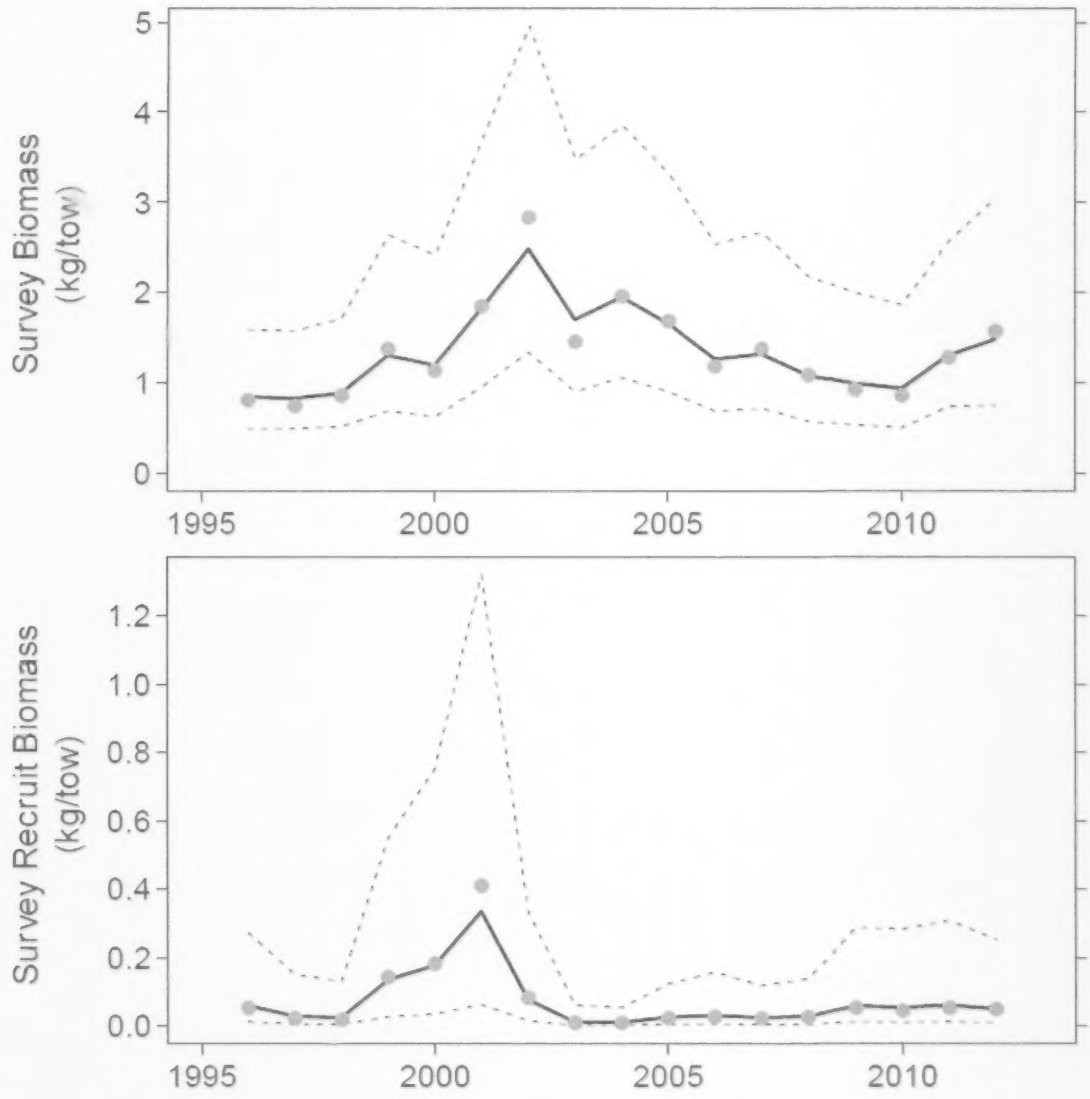

Figure 63. Posterior median fit to the survey series for commercial size and recruit size scallops. Bayesian state-space delay-difference model for scallops in SPA 3.

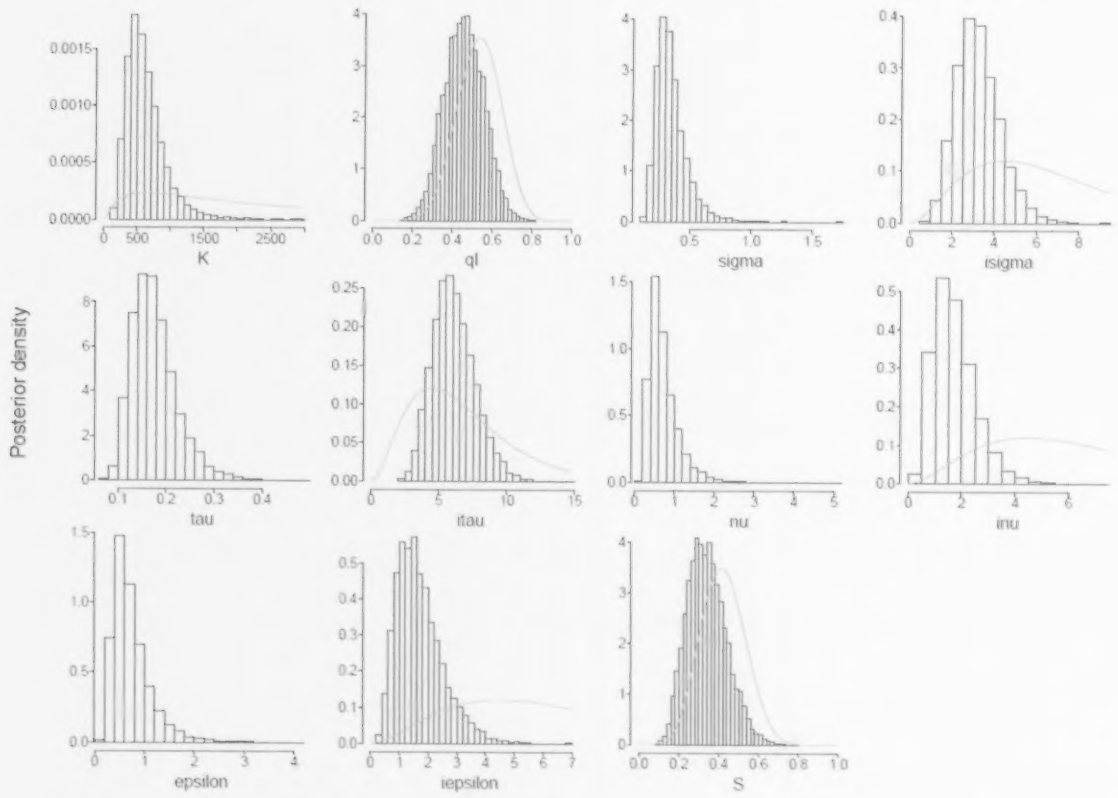

Figure 64. Comparison of prior and posterior densities. Bayesian state-space delay-difference model for scallops in SPA 3.

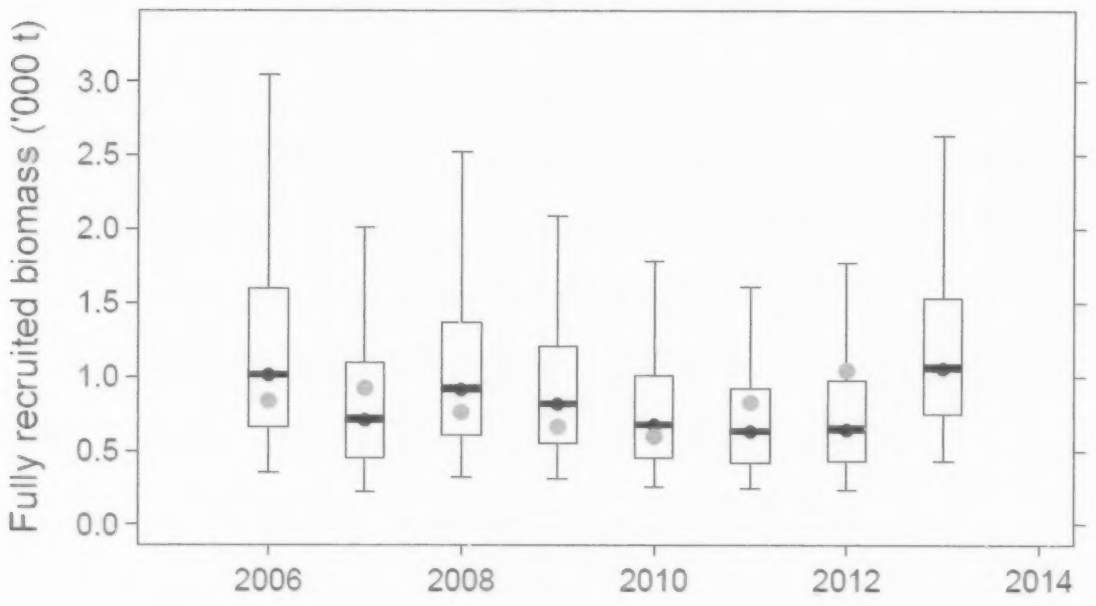

Figure 65. Evaluation of the model projection performance. Box and whisker plots summarize posterior distribution of commercial size biomass in year t based on model fit to year t-1 (e.g., 2006 prediction based on data up to 2005). Red dot represents the estimate of the biomass in year t using data up to and including year t. Bayesian state-space delay-difference model for scallops in SPA 3.

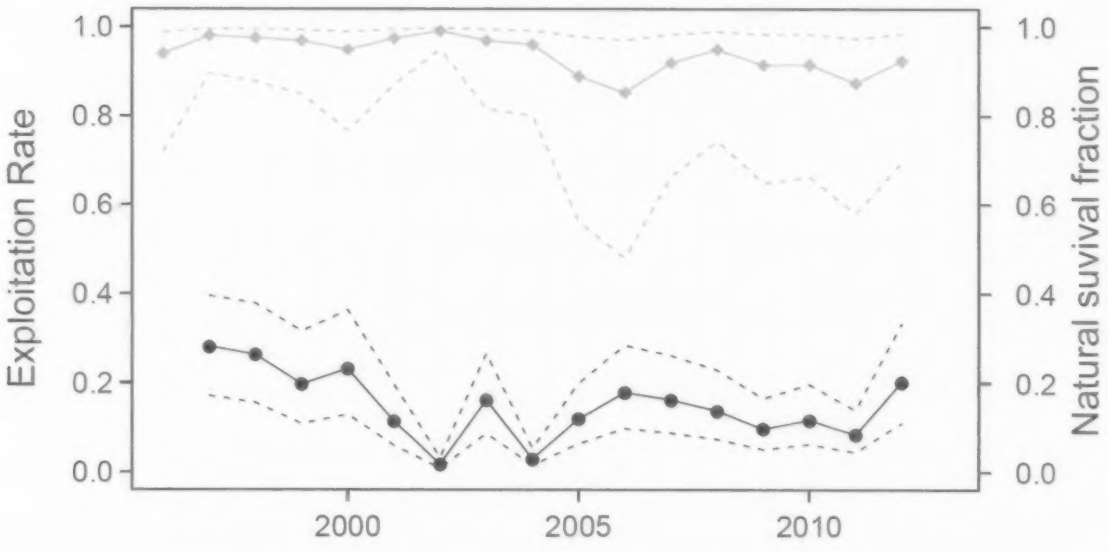

Figure 66. Annual trends in exploitation (black line, circles) and survival estimates ($exp(-m)$, where m is natural mortality; grey line, squares). Bayesian state-space delay-difference model for scallops in SPA 3.

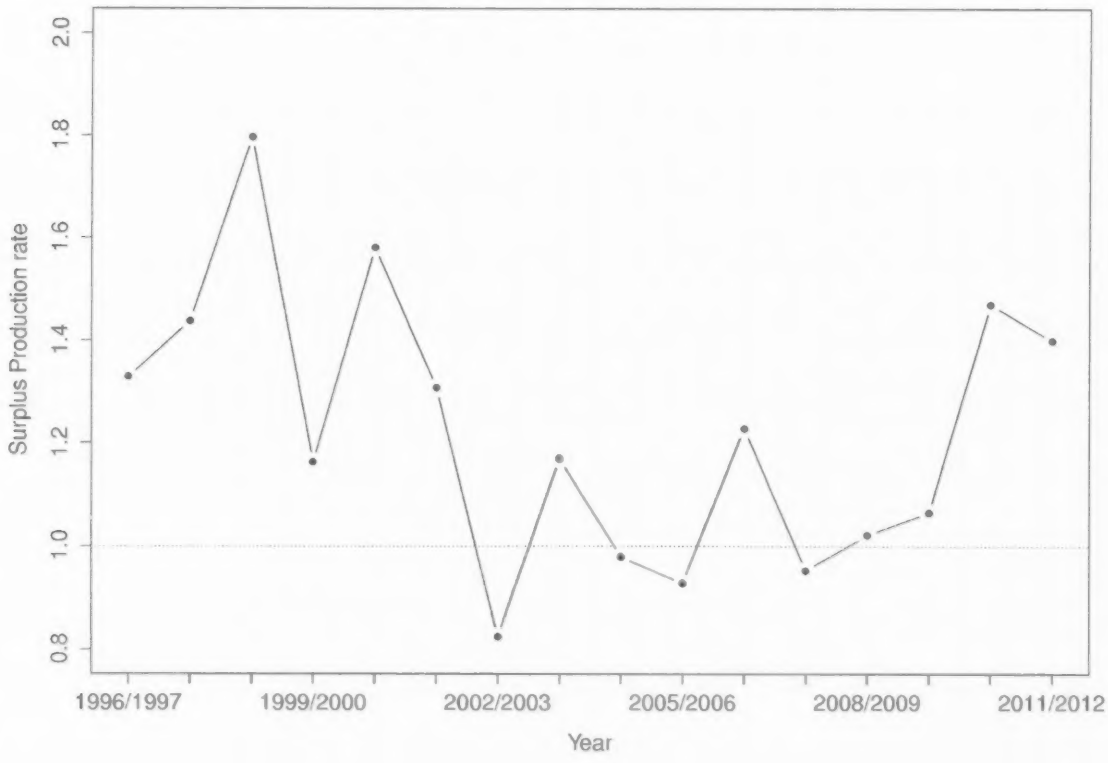

Figure 67. Surplus production rate for SPA 3. Surplus production was calculated as B_{t+1}+ C_t -B_t and surplus production rate is defined as 1 + the surplus production per scallop divided by the average weight of commercial and recruit size scallops.

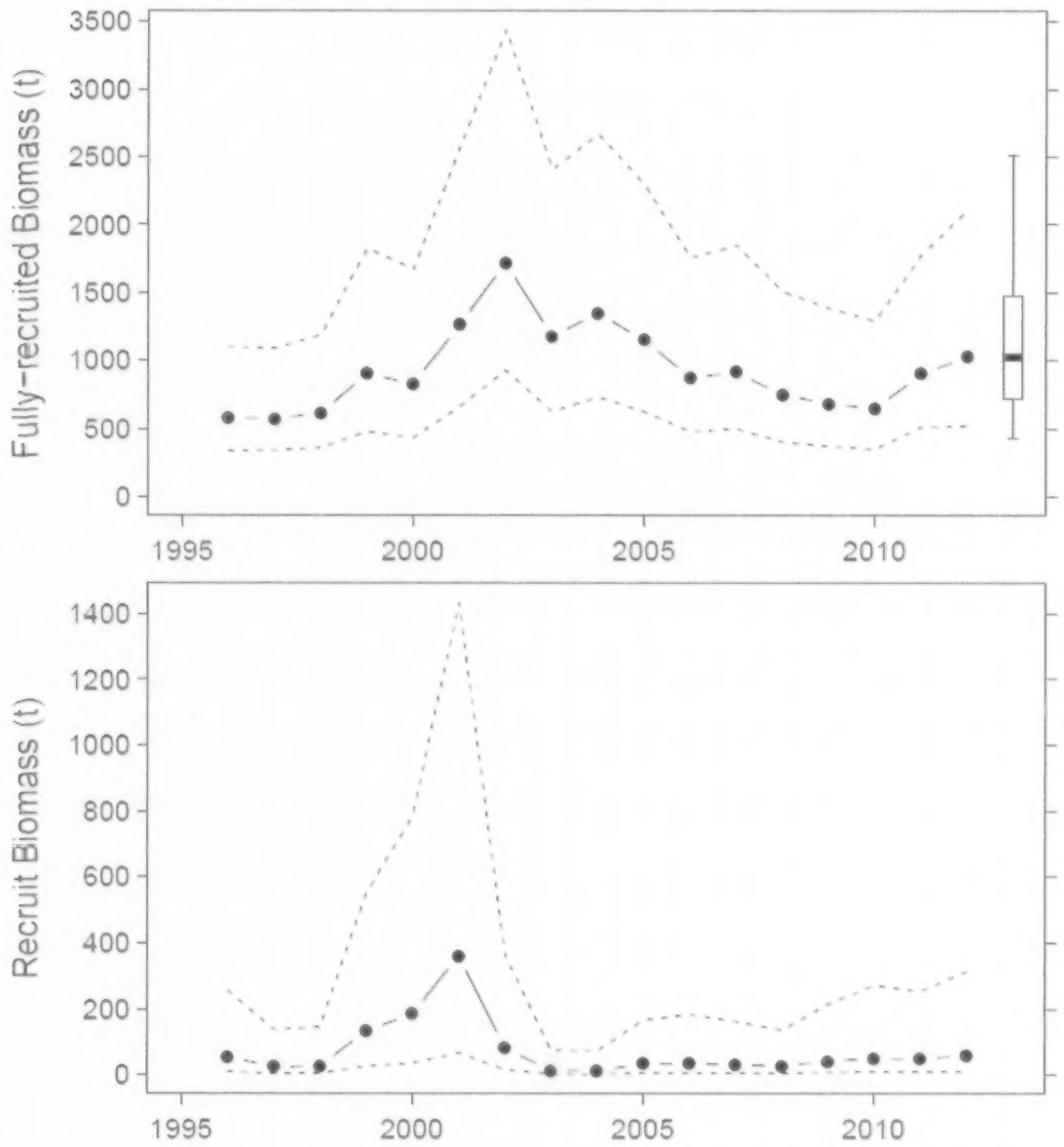

Figure 68. Biomass estimates for fully recruited scallops from the delay-difference model fit to the SPA 3 survey and commercial data. Dashed lines are the upper and lower 95% credible limits on the estimates. The predicted commercial size biomass for 2013, assuming the interim catch (143 t), is displayed as a box plot with median, 50% credible limits (box) and 80% credible limits (whiskers).

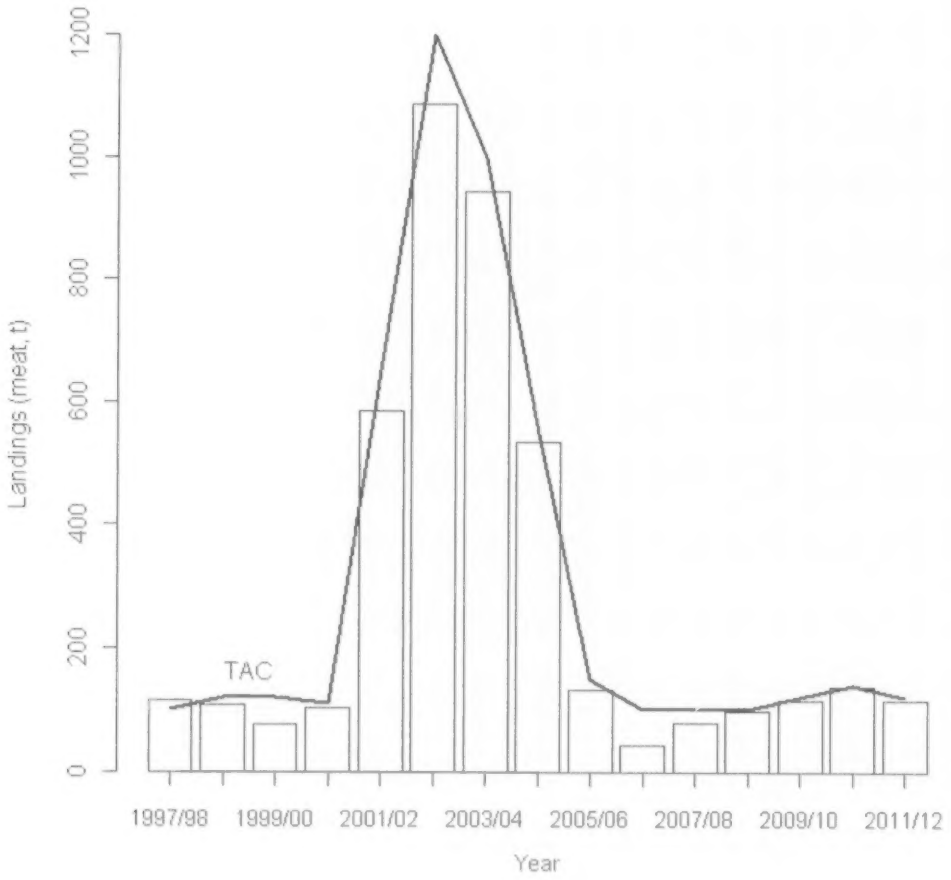

Figure 69. SPA 4 landings (meat, tons) by the Full Bay fleet.

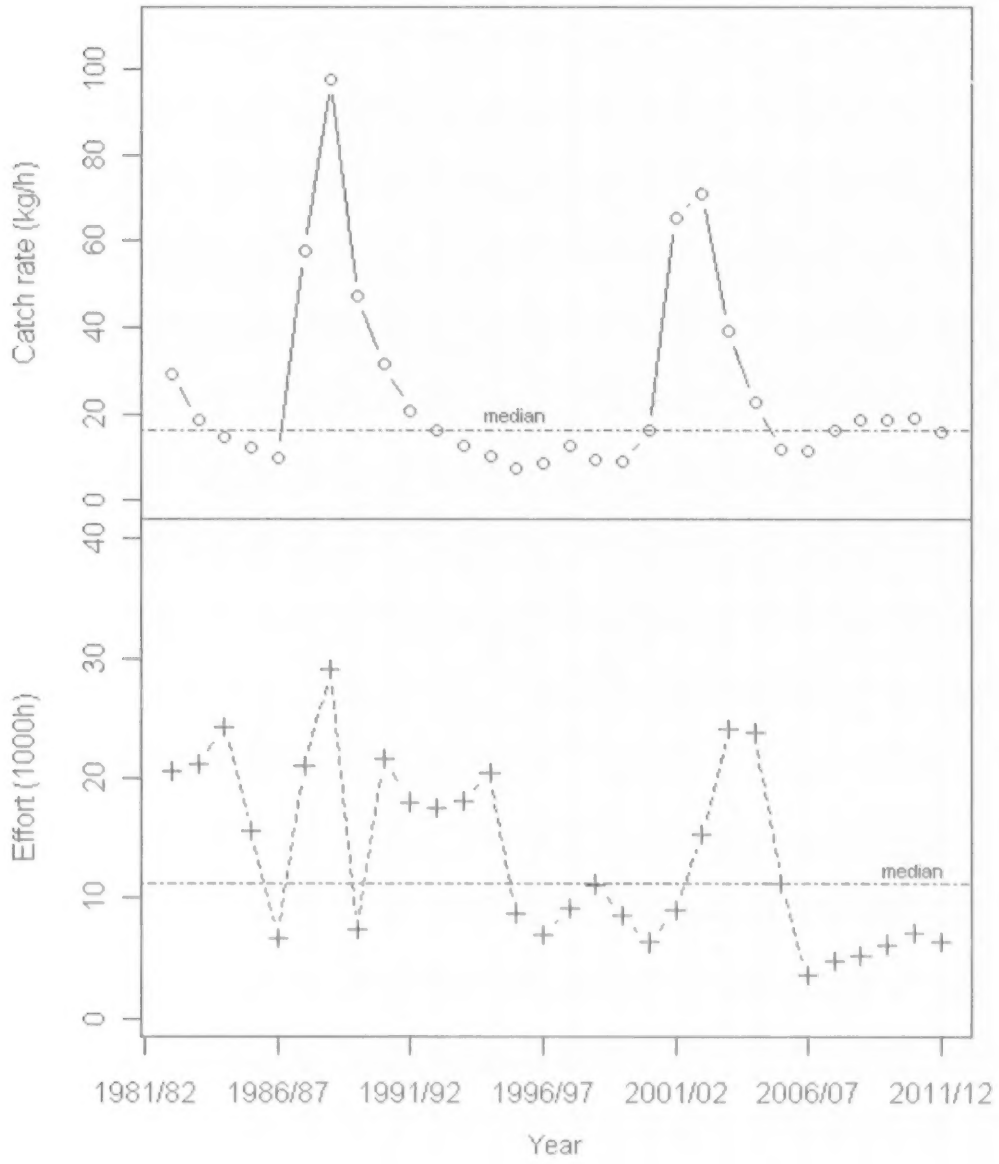

Figure 70. SPA 4 trends in catch rate (kg/h) and effort (1000h) for Full Bay fleet. Median catch rate and effort from 1982/83 to 2010/2011 indicated.

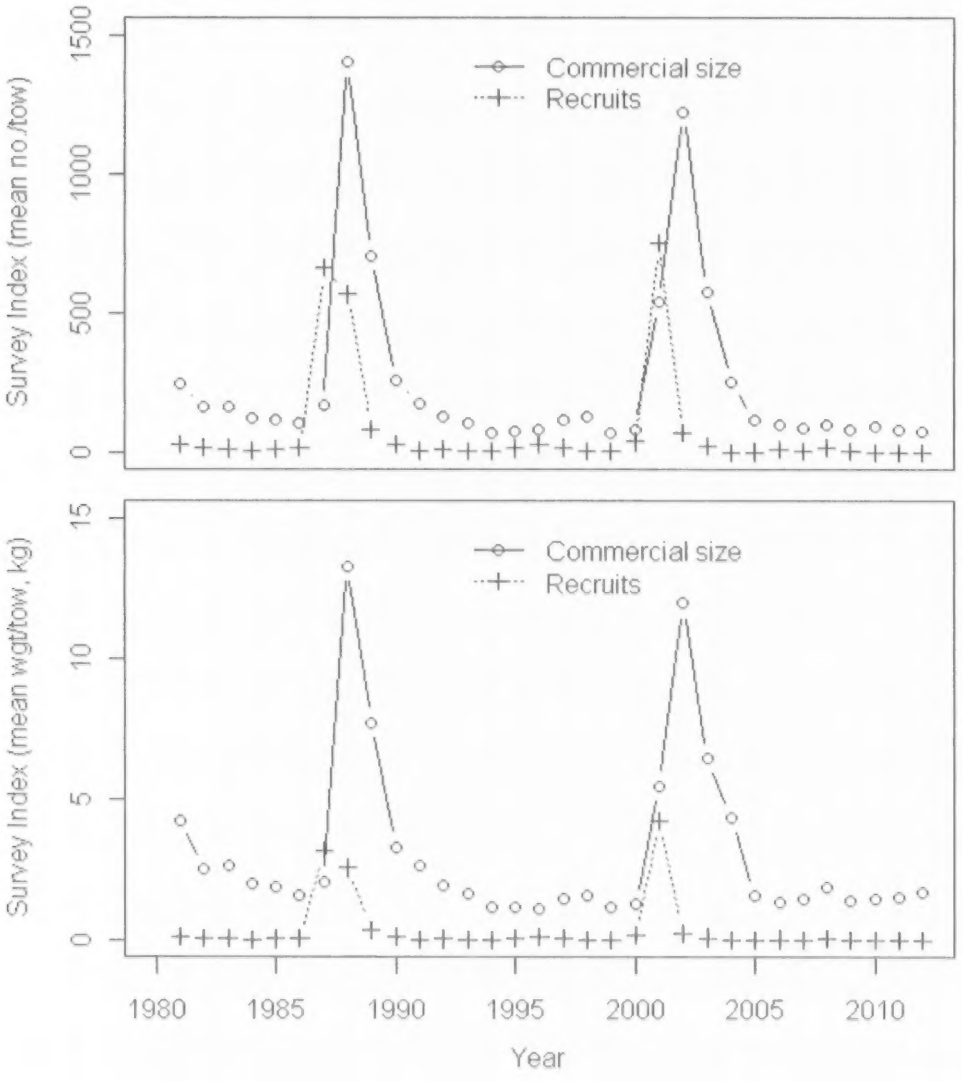

Figure 71. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for SPA 4.

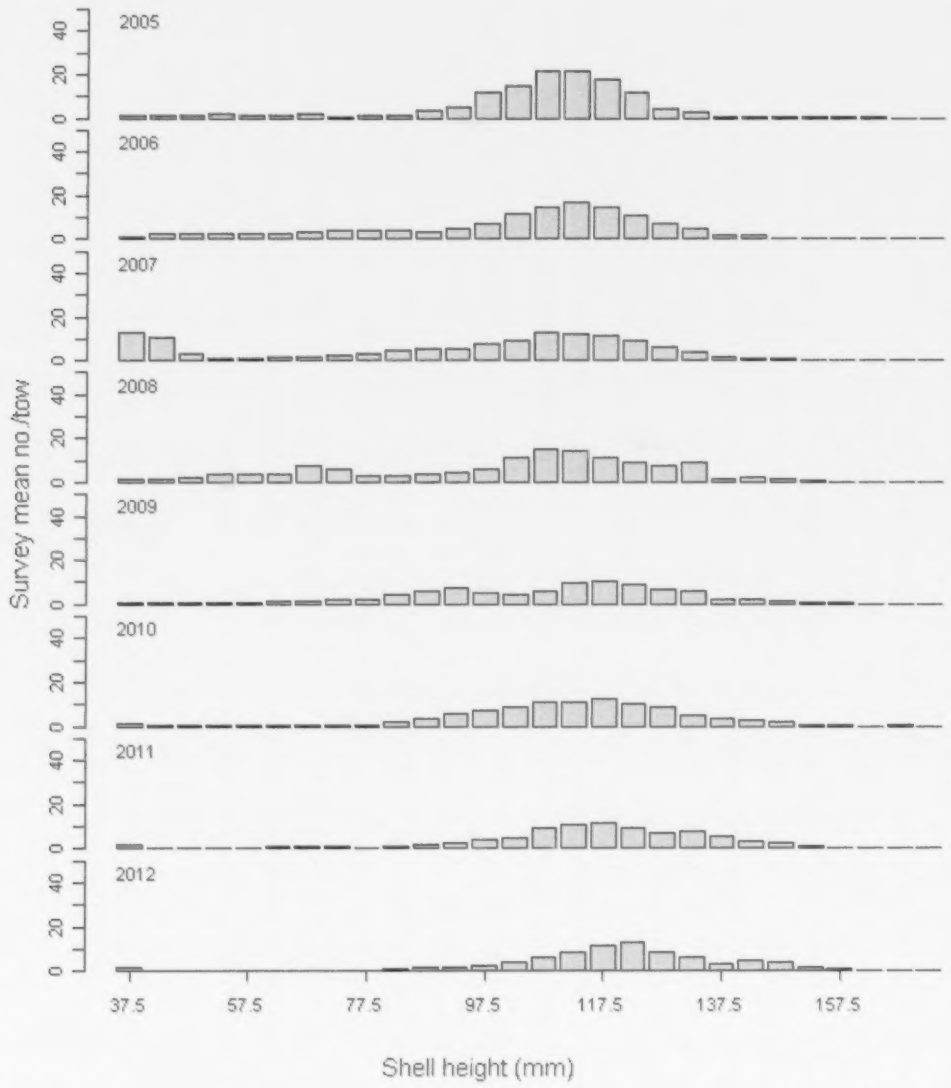

Figure 72. Scallop survey shell height frequencies (mean number/tow) for SPA 4.

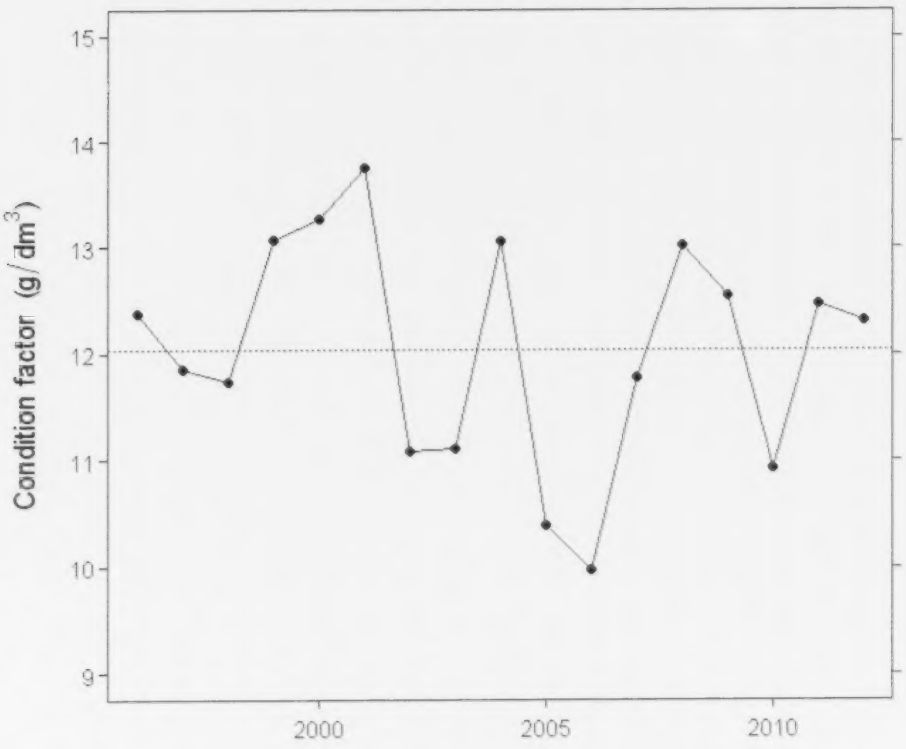

Figure 73. SPA 4 trend in condition factor (g/dm^3) from the annual survey.

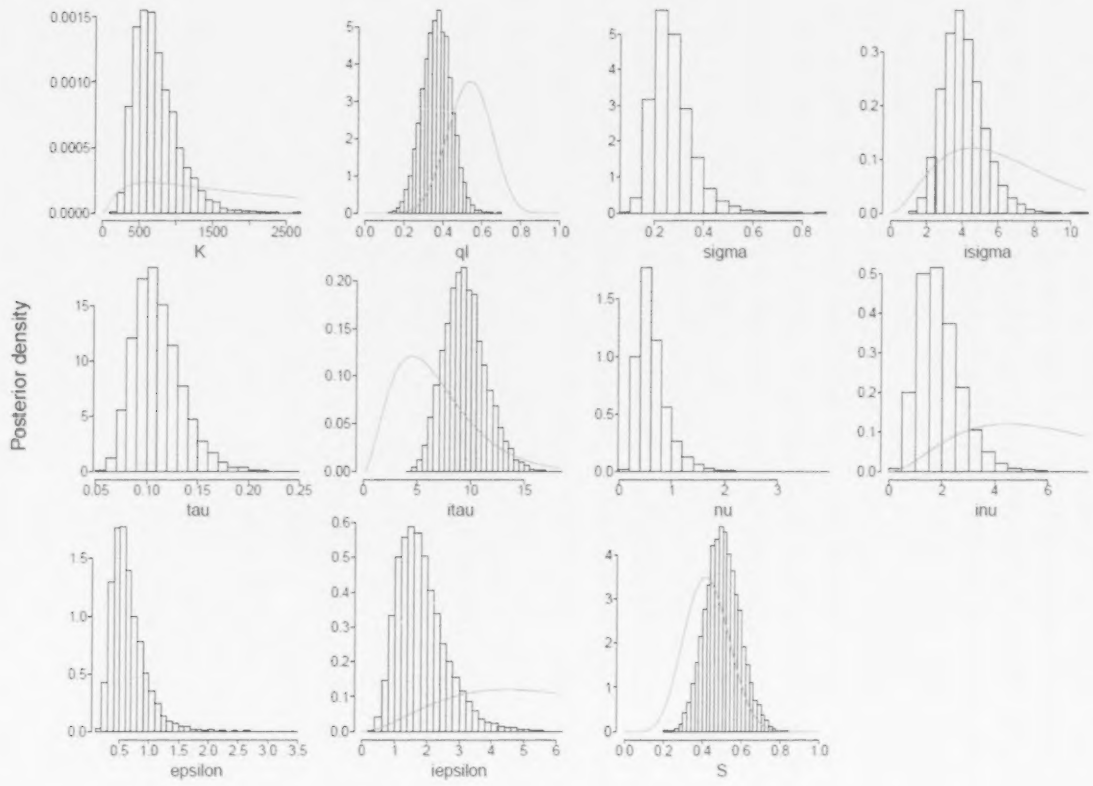

Figure 74. Comparison of prior and posterior densities. Bayesian state-space delay-difference model for scallops in SPA 4.

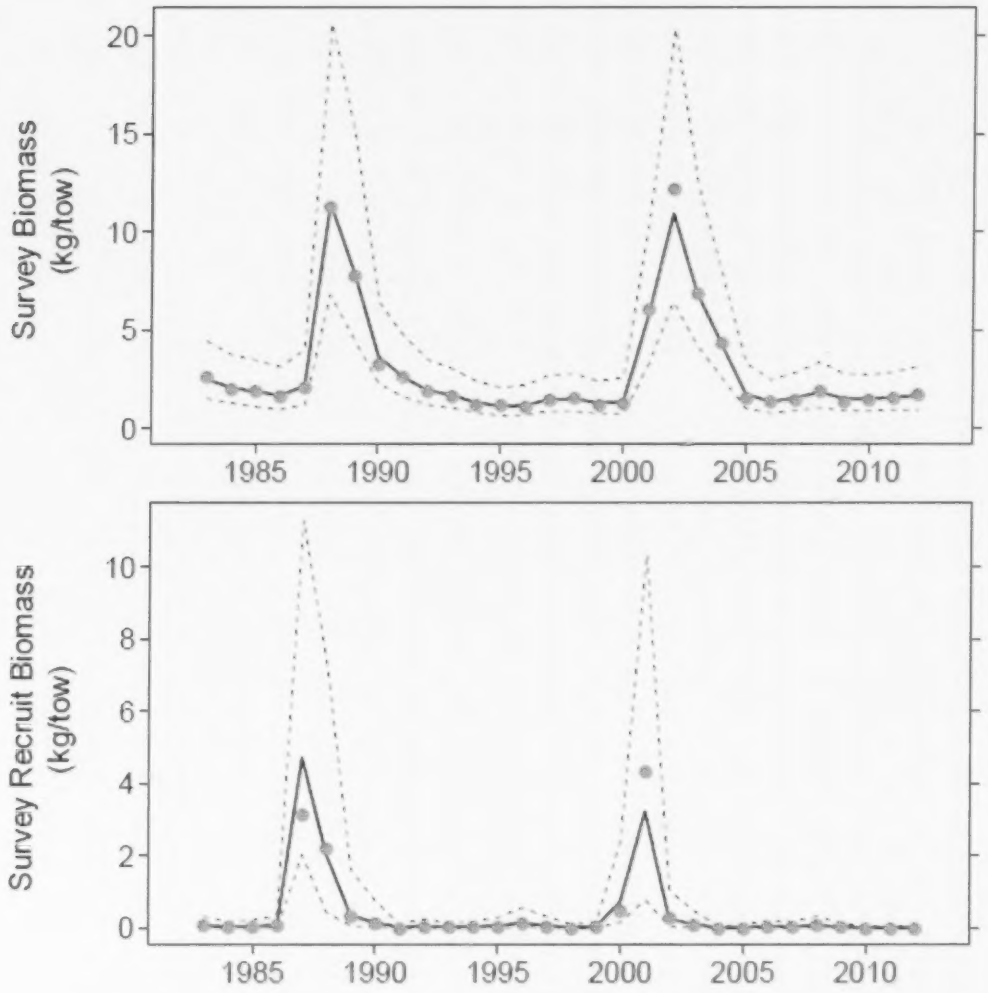

Figure 75. Posterior median fit to the survey series for commercial size and recruit size scallops. Bayesian state-space delay-difference model for scallops in SPA 4.

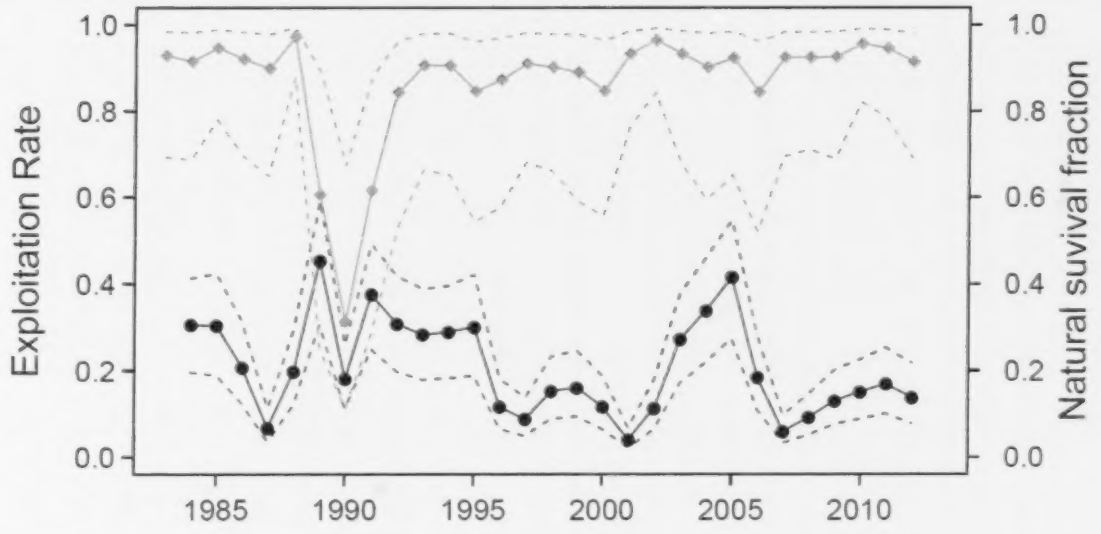

Figure 76. Annual trends in exploitation (black line, circles) and survival estimates ($exp(-m)$, where m is natural mortality; grey line, squares). Bayesian state-space delay-difference model for scallops in SPA 4.

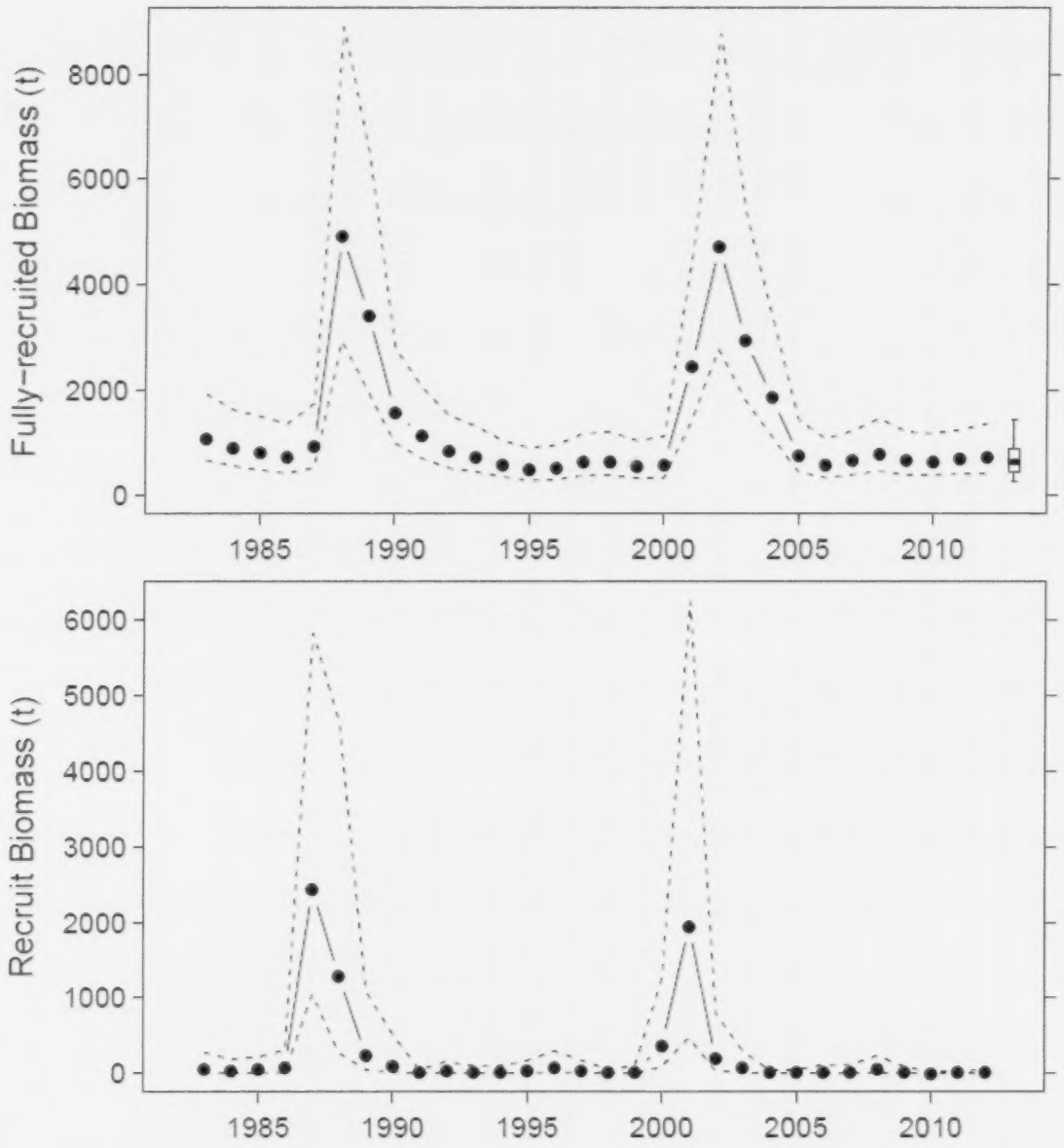

Figure 77. Biomass estimates for fully recruited scallops from the delay-difference model fit to the SPA 4 survey and commercial data. Dashed lines are the upper and lower 95% credible limits on the estimates. The predicted commercial size biomass for 2013, assuming the interim TAC (100 t), is displayed as a box plot with median, 50% credible limits (box) and 80% credible limits (whiskers).

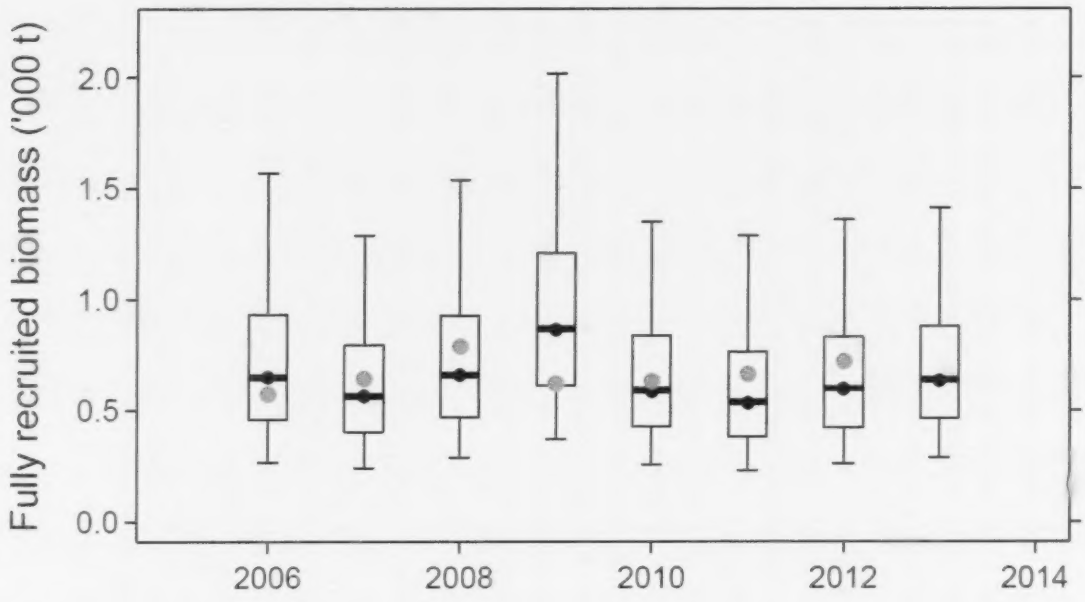

Figure 78. Evaluation of the model projection performance. Box and whisker plots summarize posterior distribution of commercial size biomass in year t based on model fit to year t-1 (e.g., 2006 prediction based on data up to 2005). Red dot represents the estimate of the biomass in year t using data up to and including year t. Bayesian state-space delay-difference model for scallops in SPA 4.

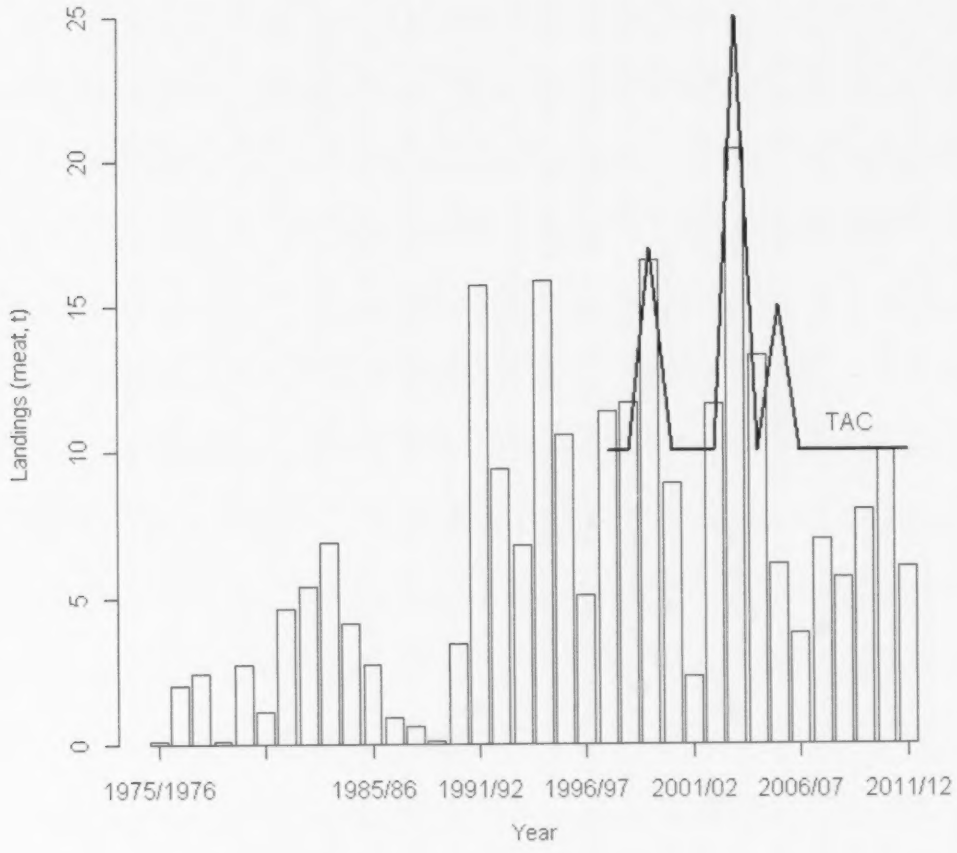

Figure 79. SPA 5 landings (meat, tons) by the Full Bay fleet.

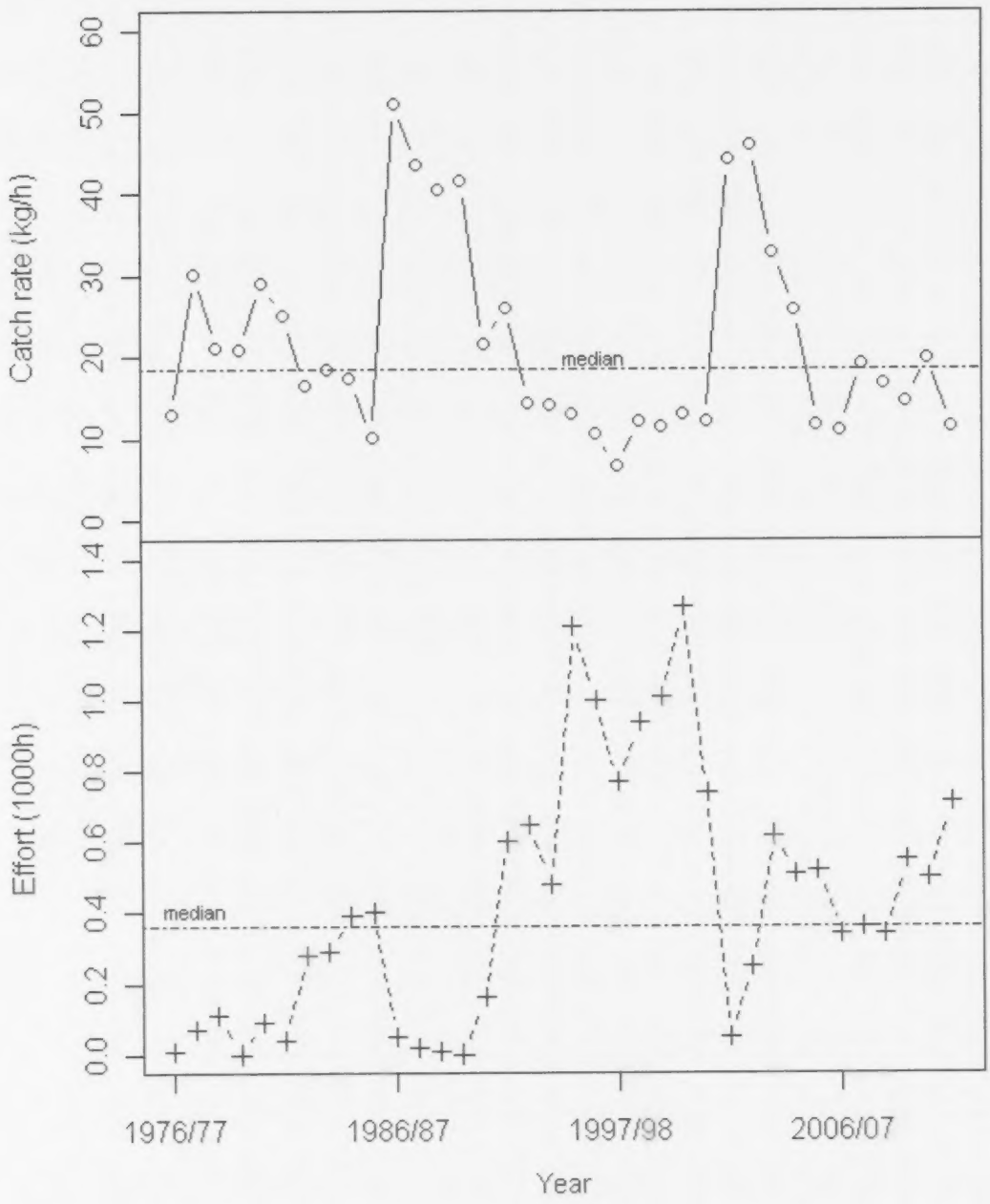

Figure 80. SPA 5 trends in catch rate (kg/h) and effort (1000h) for Full Bay fleet. Median catch rate and effort from 1975/1976 to 2010/2011 indicated.

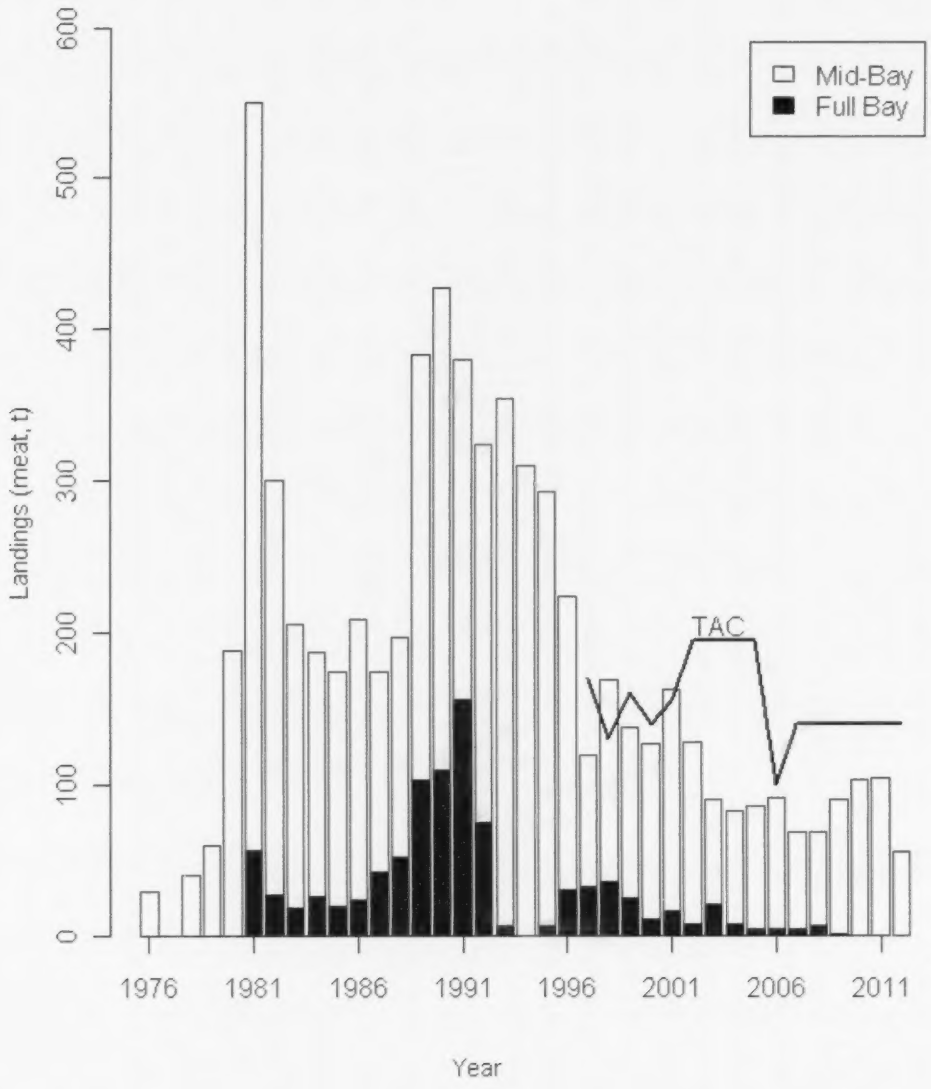

Figure 81. SPA 6 landings (meat, tons) by fleet.

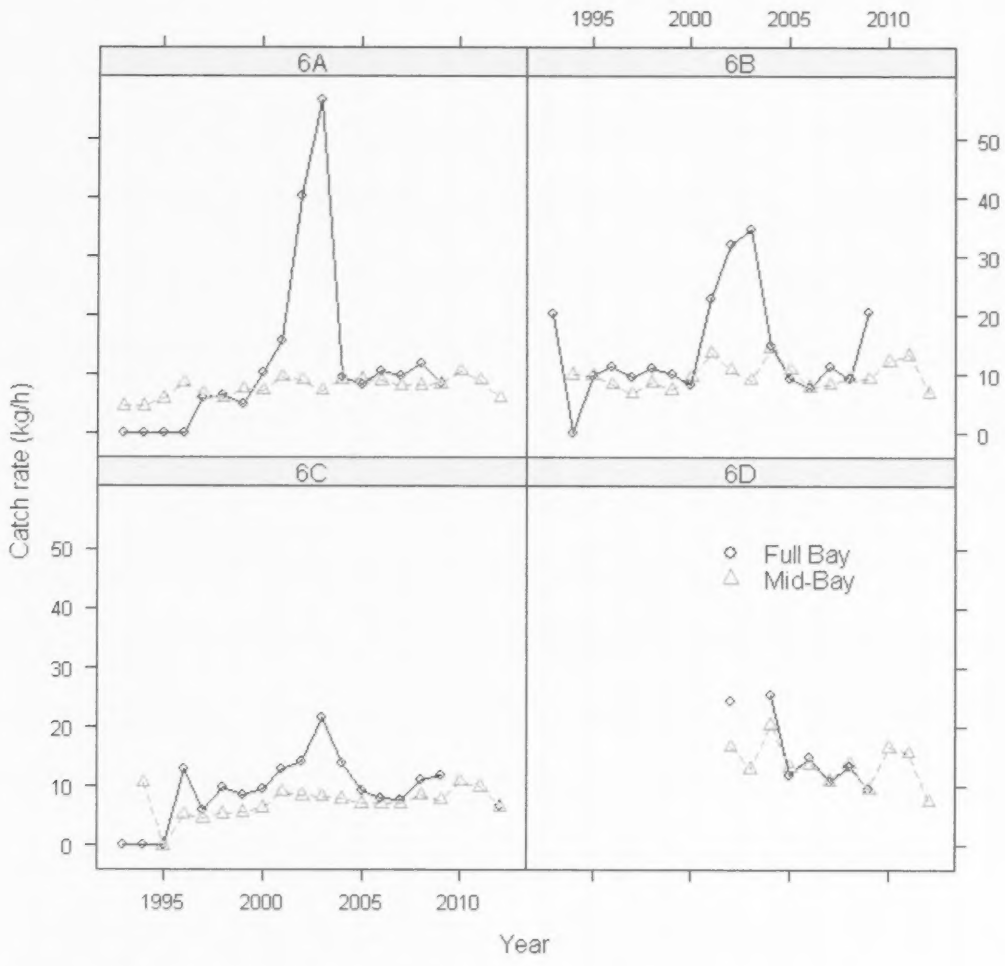

Figure 82. SPA 6 trends in catch rate (kg/h) in each subarea for each fleet.

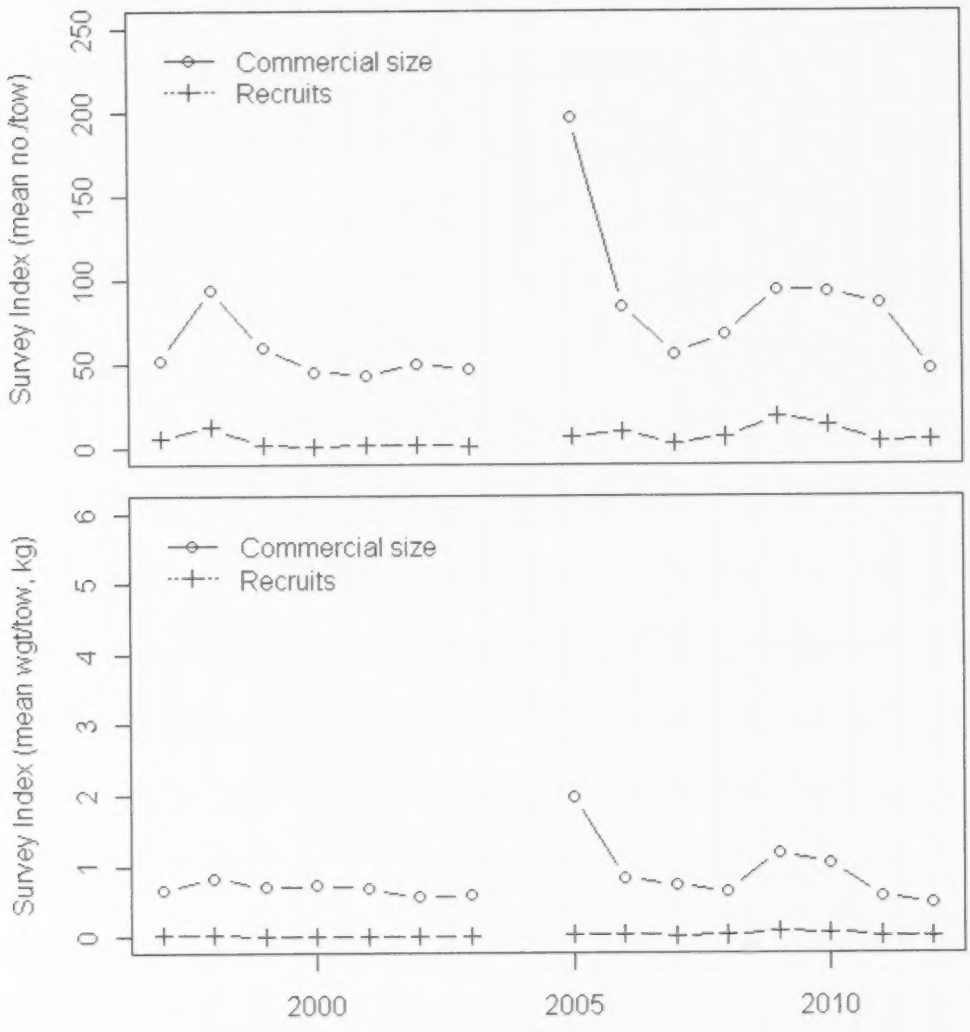

Figure 83. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for SPA 6A.

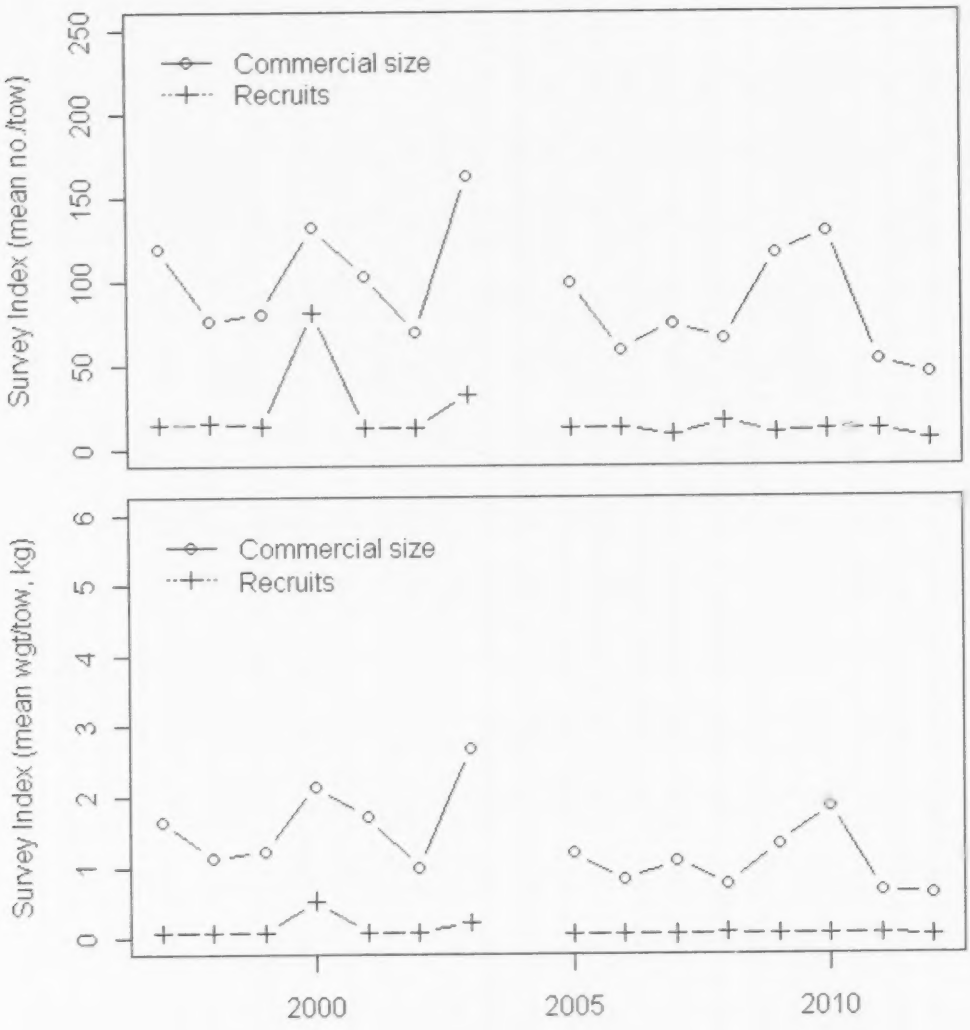

Figure 84. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for SPA 6B.

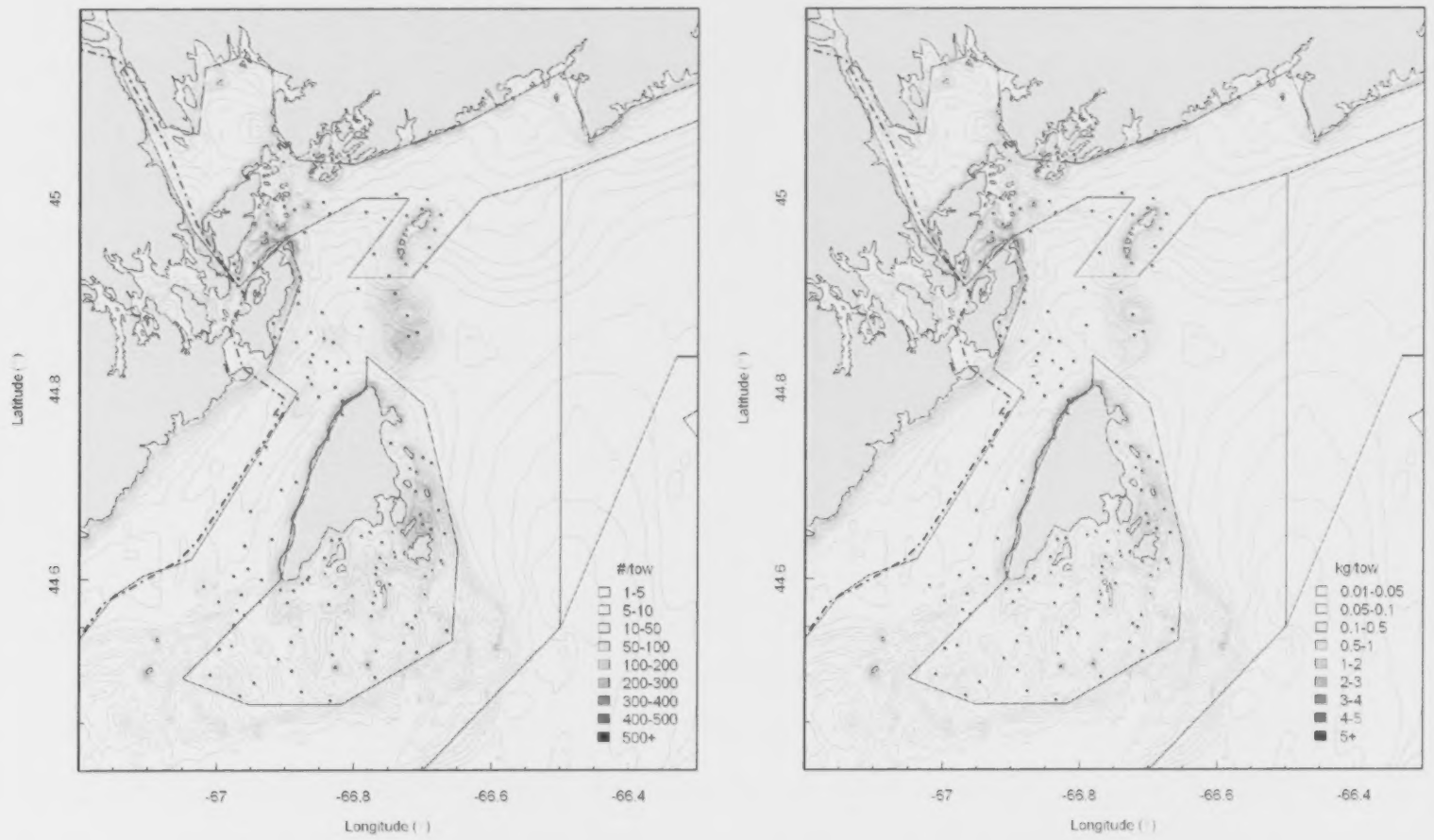

Figure 85. Spatial density of number/tow (left) and kg/tow (right) of recruit scallop (65-79 mm) from the 2012 survey for SPA 6.

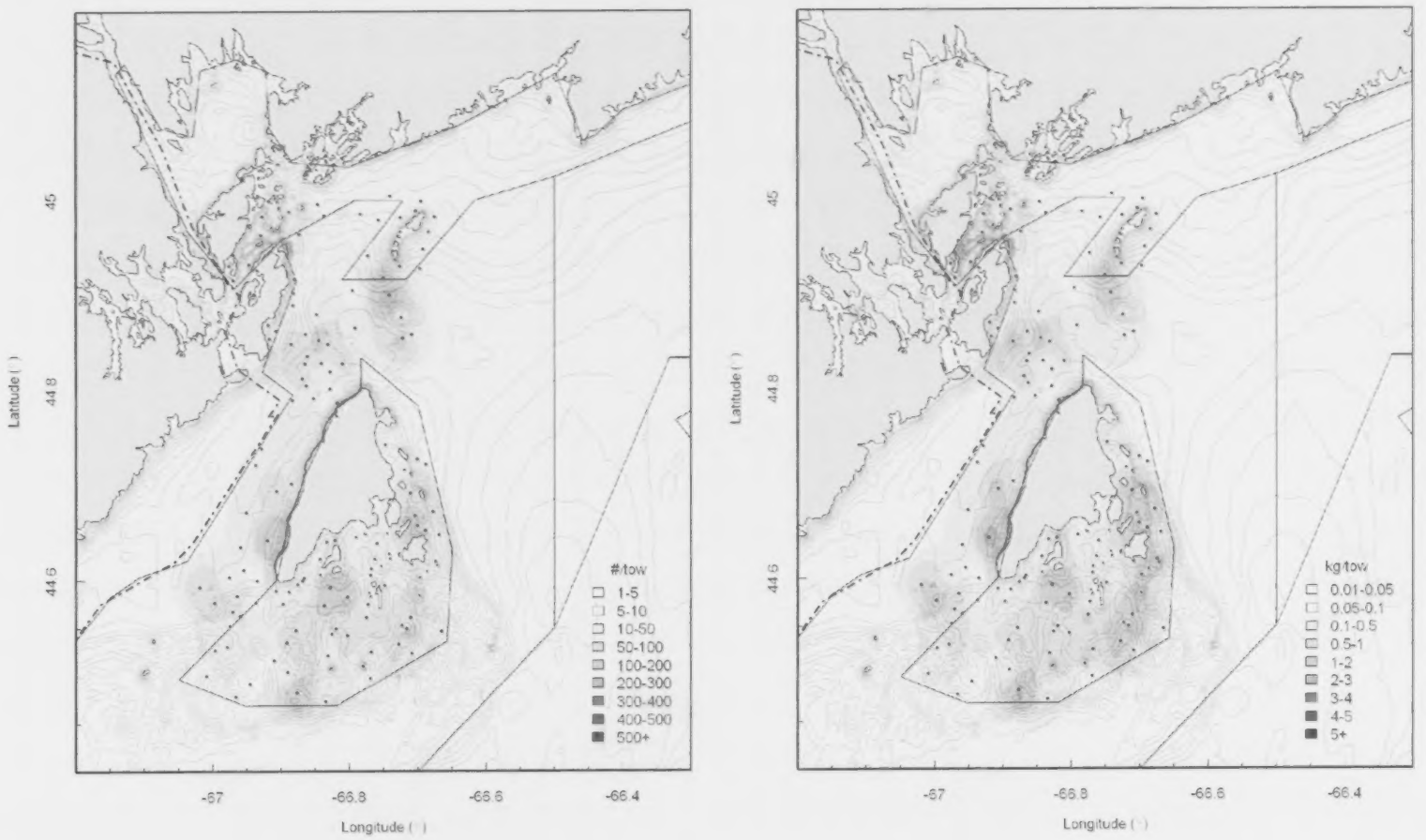

Figure 86. Spatial density of number/tow (left) and kg/tow (right) of commercial scallop (≥80 mm) from the 2012 survey for SPA 6.

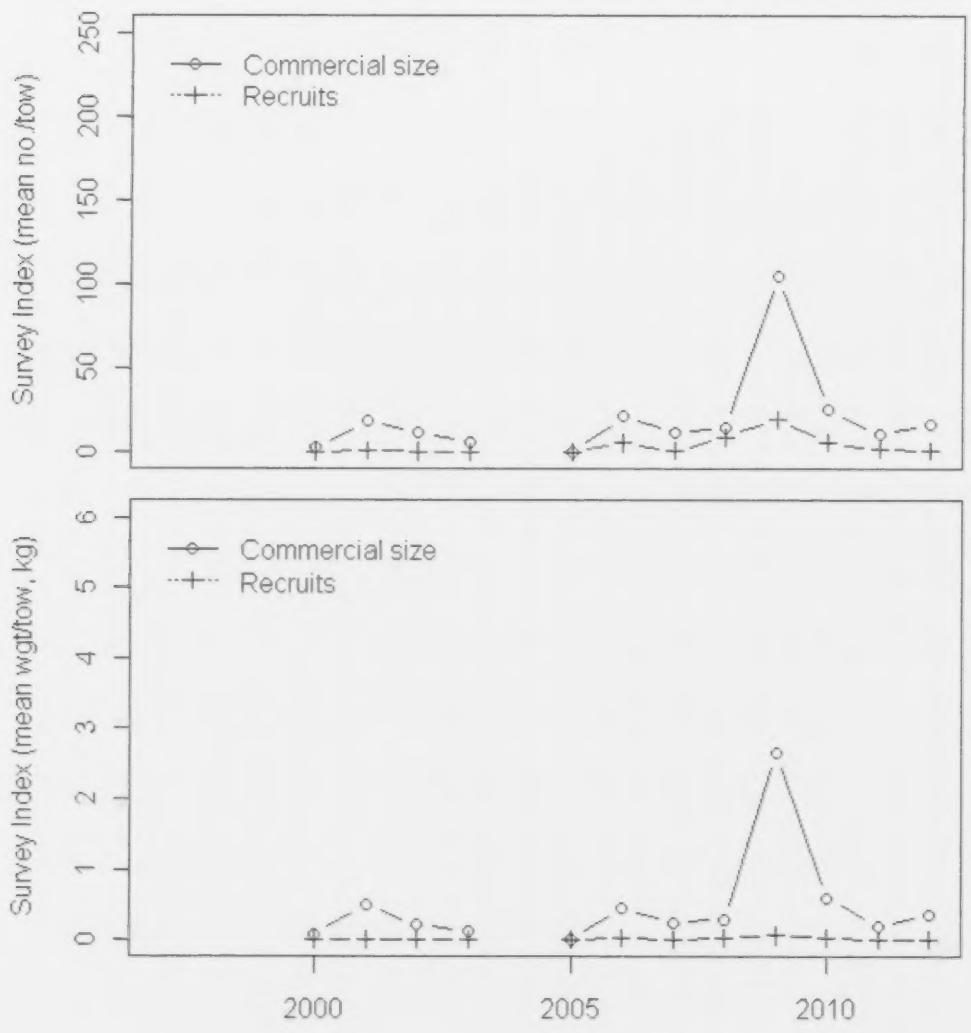

Figure 87. Survey abundance index (upper; mean number/tow) and biomass (lower; mean kg/tow) for recruit (65-79 mm) and commercial (≥80 mm) scallops for SPA 6C.

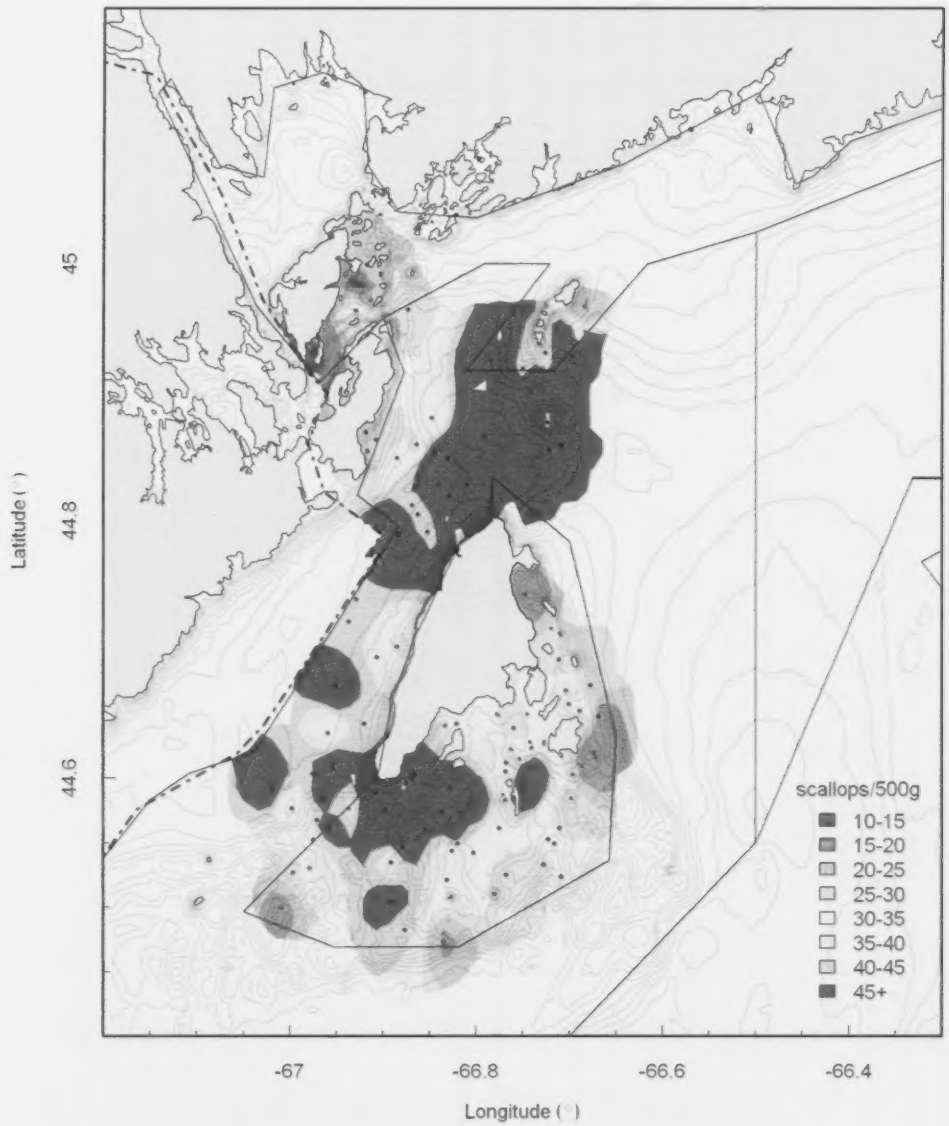

Figure 88. Spatial distribution of meat count (scallop/500 g) from the 2012 survey for SPA 6.

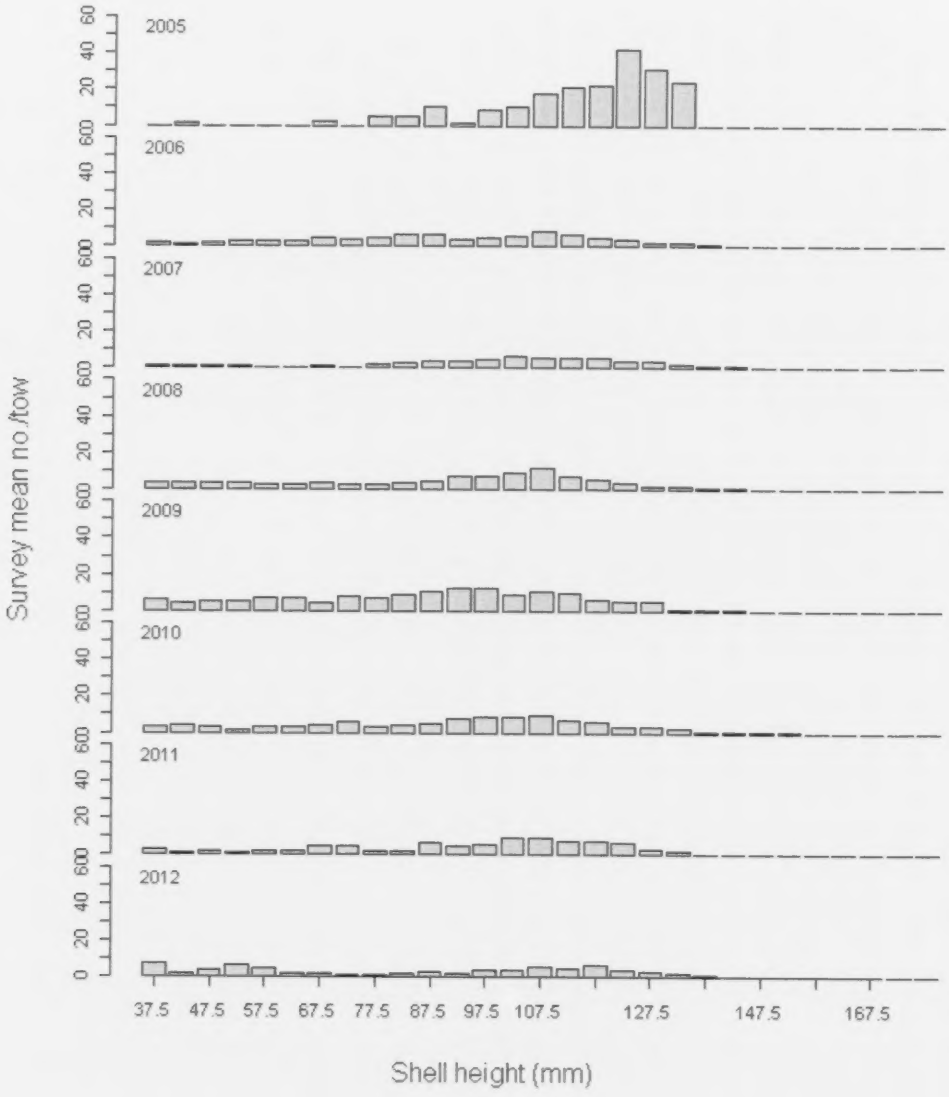

Figure 89. Scallop survey shell height frequencies (mean number/tow) for SPA 6A.

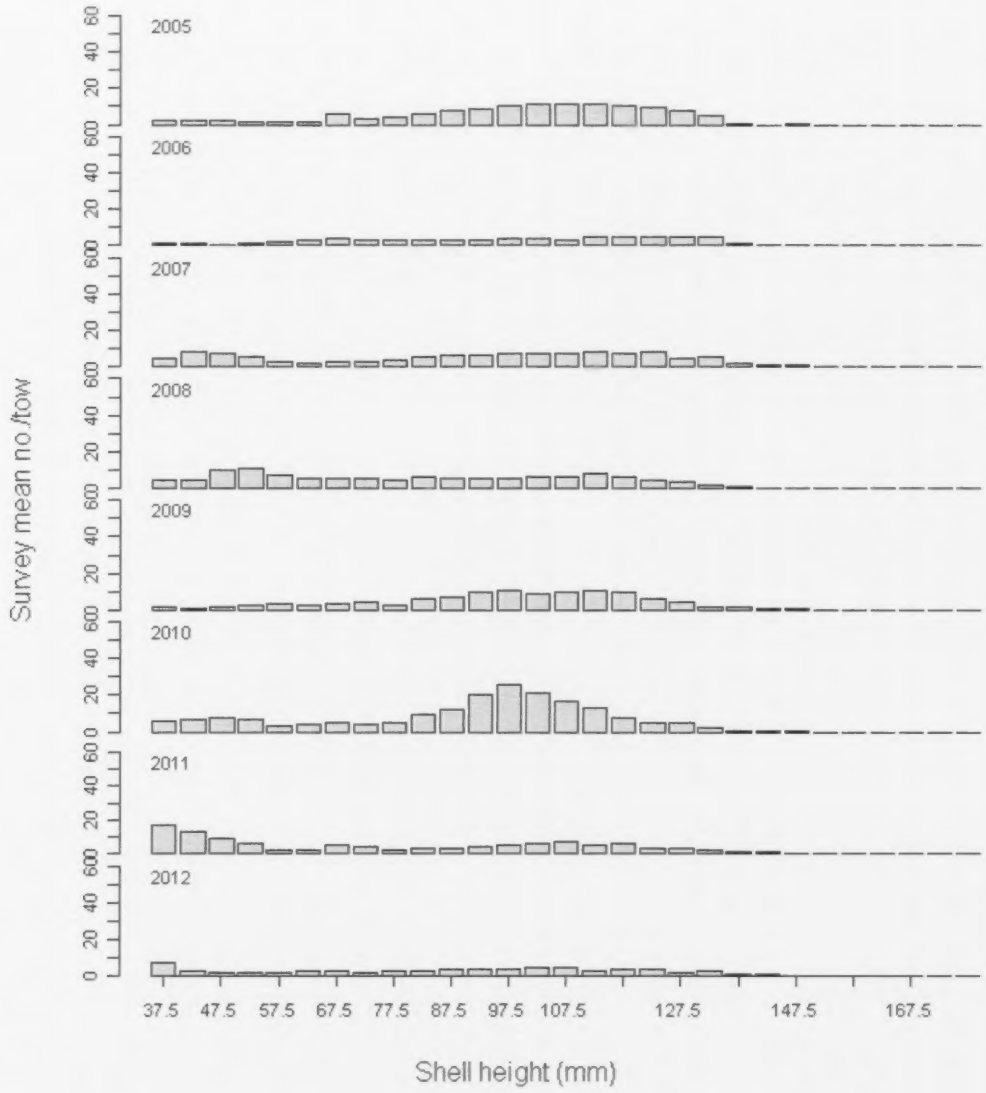

Figure 90. Scallop survey shell height frequencies (mean number/tow) for SPA 6B.

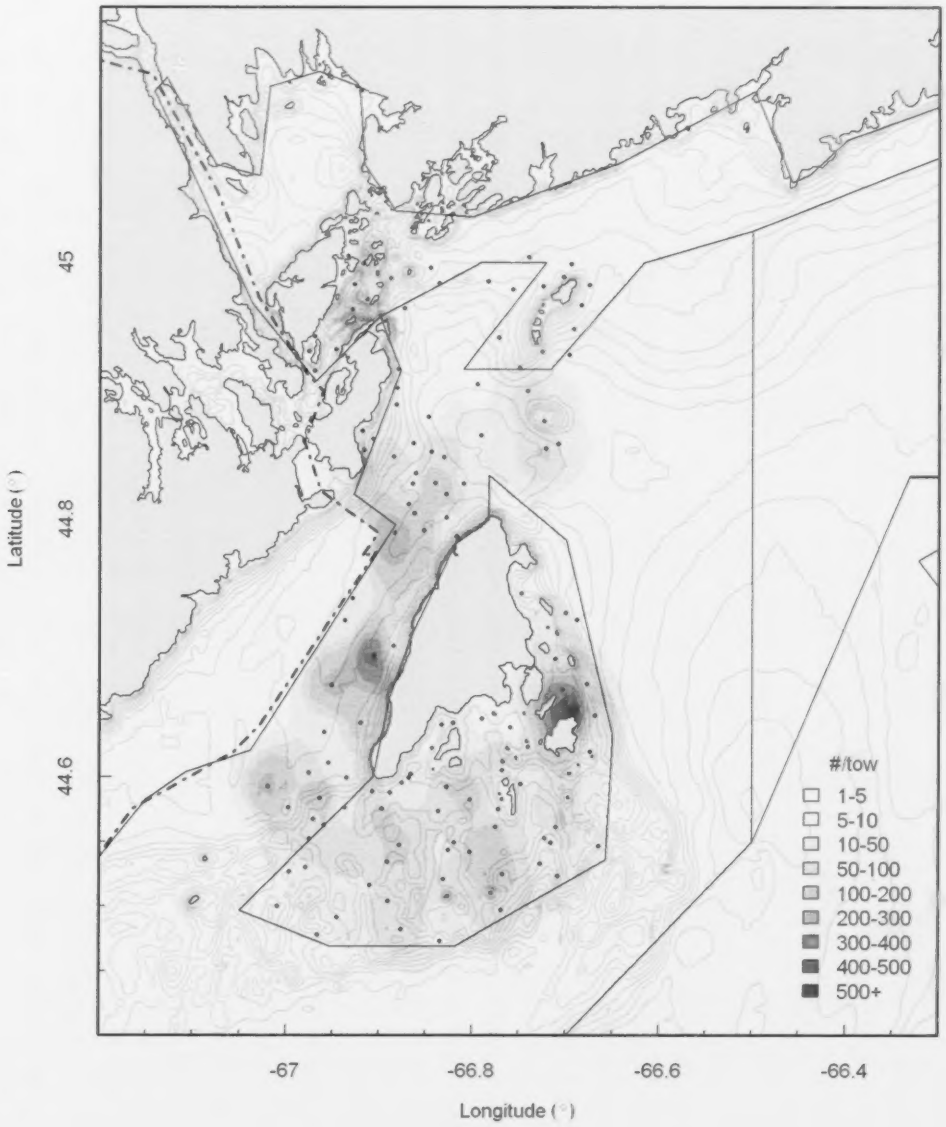

Figure 91. Spatial density (number/tow) of pre-recruit scallop (<65 mm) from the 2012 survey for SPA 6.

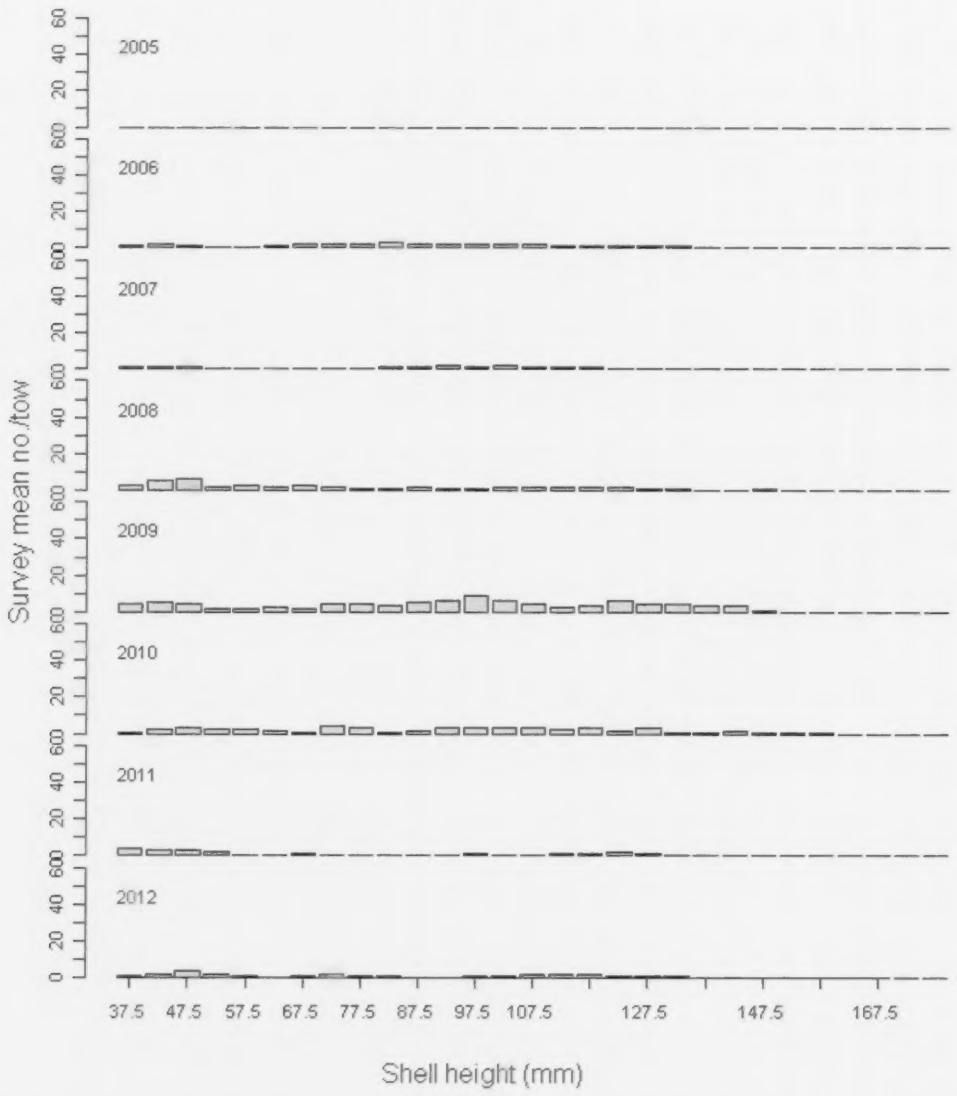

Figure 92. Scallop survey shell height frequencies (mean number/tow) for SPA 6C.

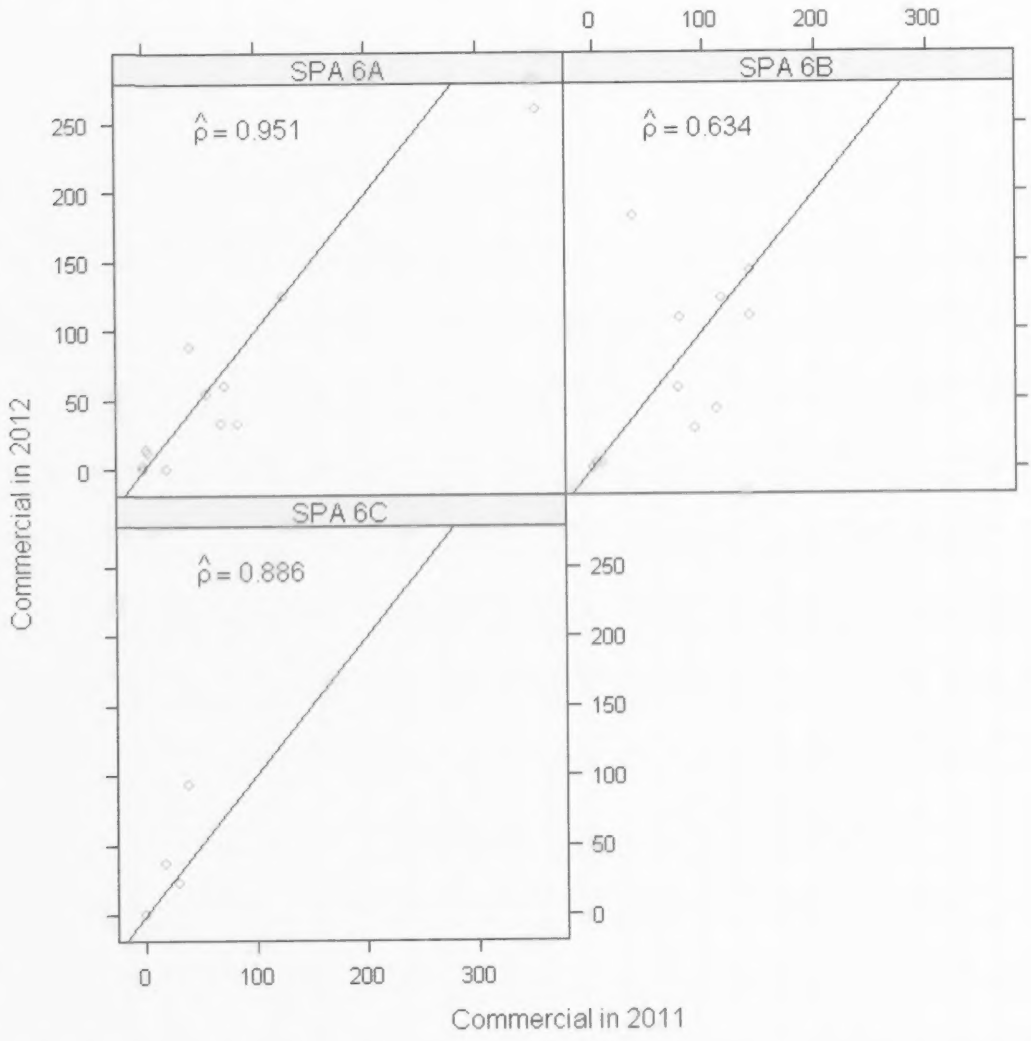

Figure 93. Comparing numbers of commercial (≥80 mm) scallop caught in 2011 and 2012 in the repeated survey stations in SPA 6. Solid line indicates 1:1 line.

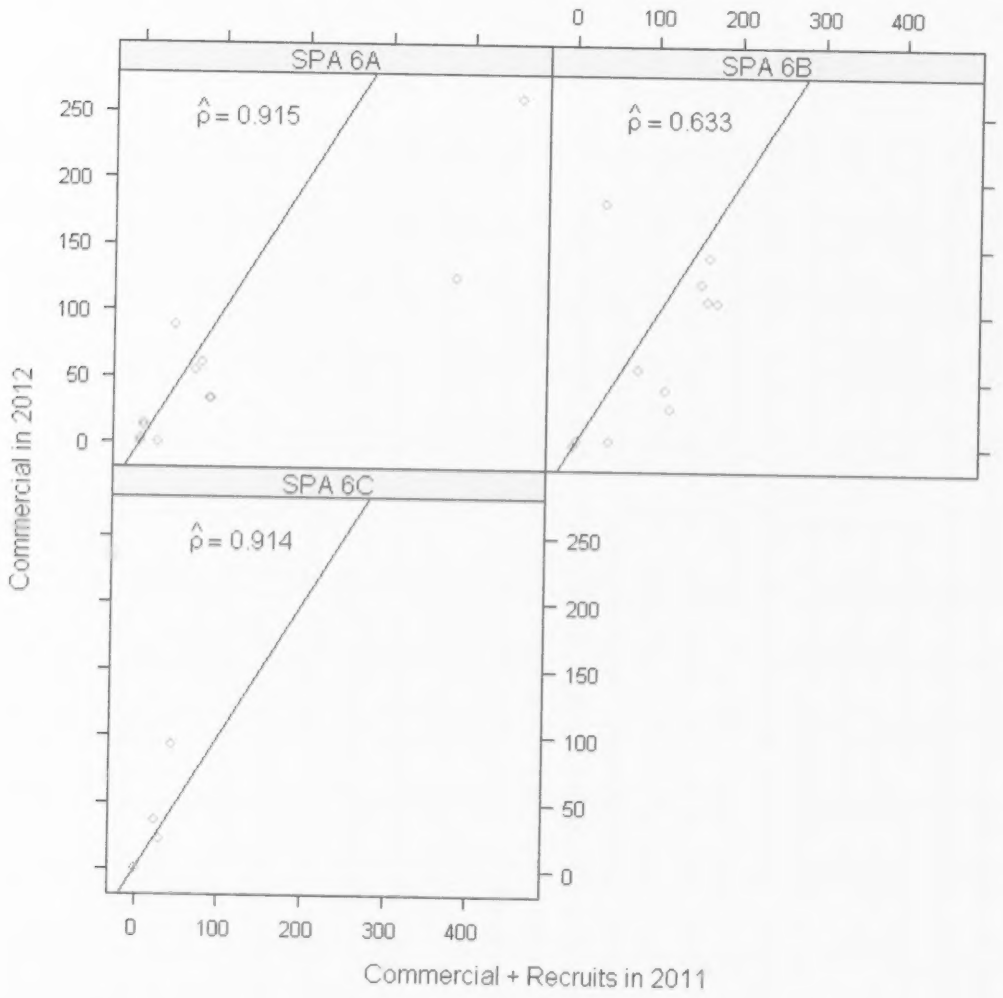

Figure 94. Comparing numbers of commercial (≥80 mm) and recruits (65-79 mm) scallop caught in 2011 and commercial scallop caught in 2012 in the repeated survey stations in SPA 6. Solid line indicates 1:1 line.

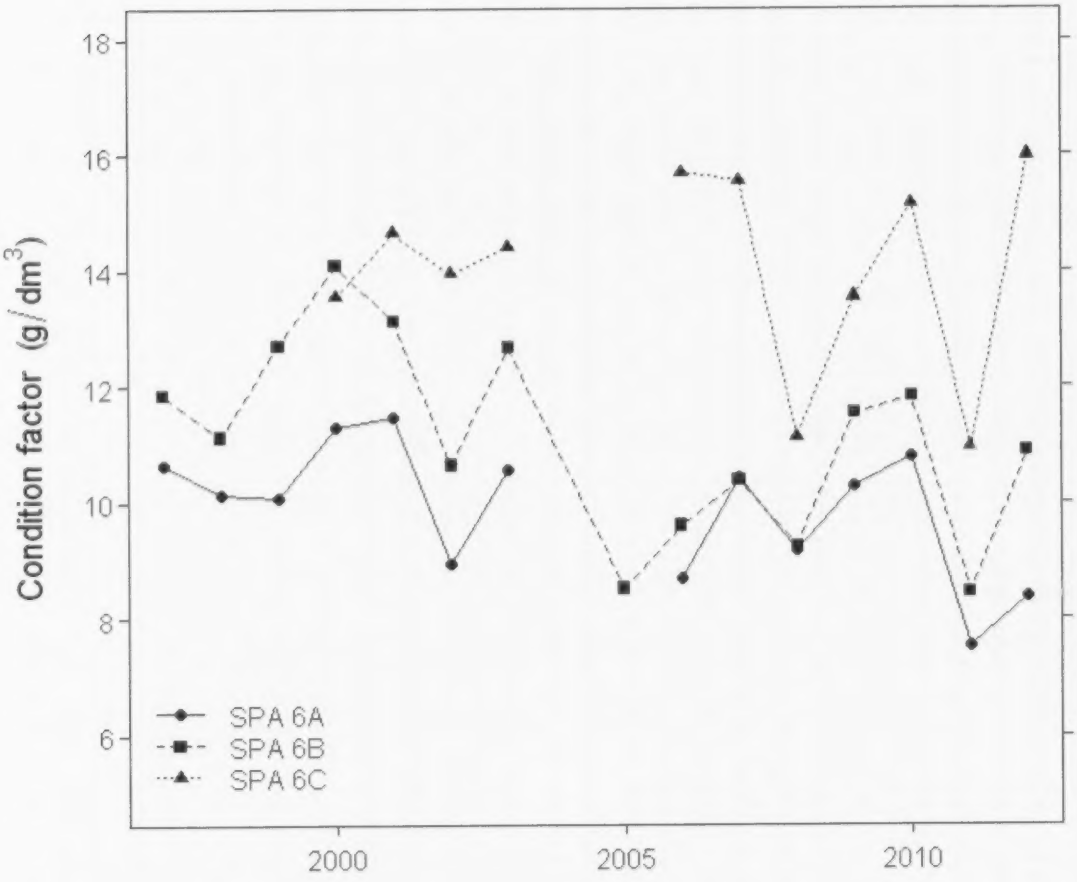

Figure 95. SPA 6 trend in condition factor (g/dm^3) from the annual survey.

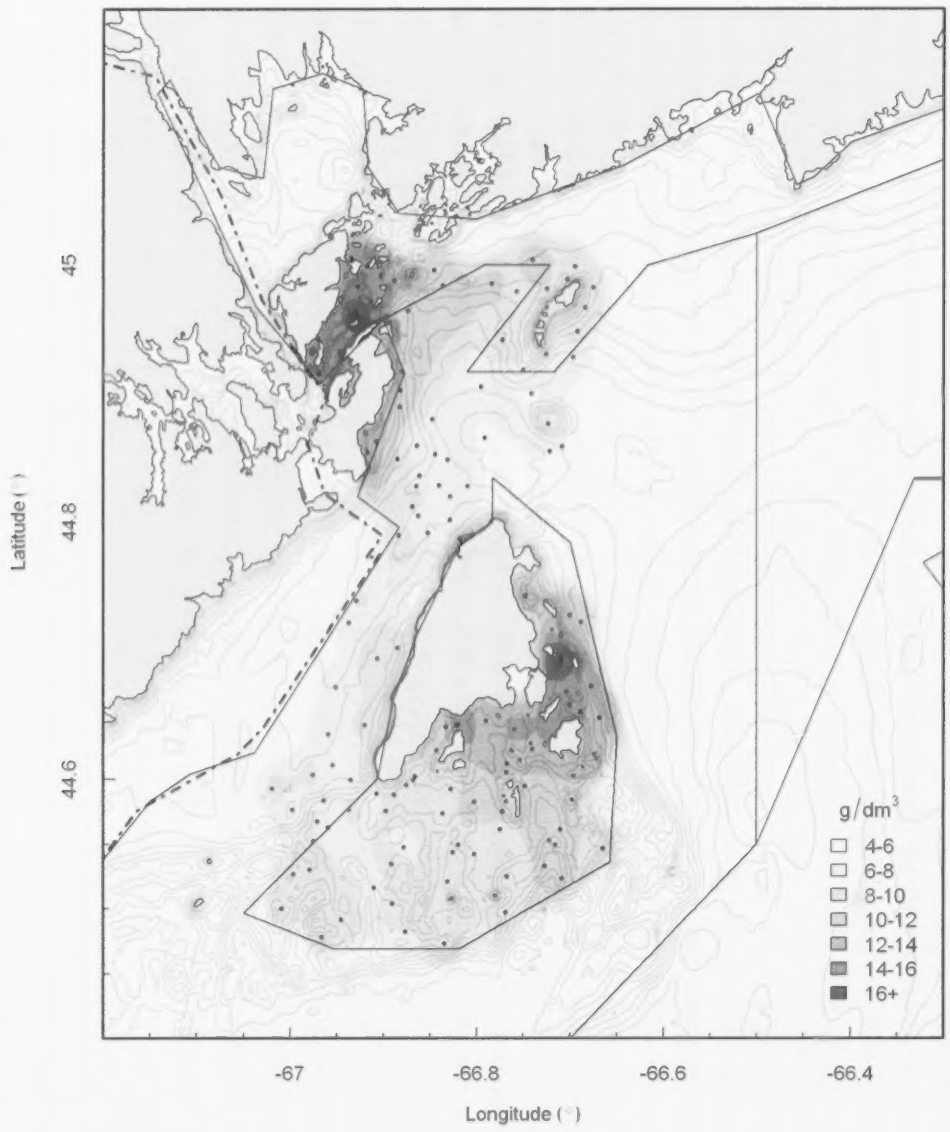

Figure 96. Spatial distribution of condition factor (g/dm^3) from the 2012 survey for SPA 6.